Greeninfra 4 Beira

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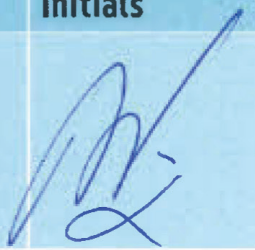
Final	June 2015	Piet Kalsbeek		Peter Letitre		Henriette Otter	

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1 Introduction

1.1 Background

The urban population of the world has grown rapidly since 1950, from 746 million to 3.9 billion in 2014 (World Bank). As the world continues to urbanize, sustainable development challenges will be increasingly concentrated in cities. Unplanned urban growth threatens sustainable development when the necessary infrastructure is not developed.
Beira is one of the fast growing economic centres in Mozambique, which leads to increasing urbanization of this coastal city. For this reason, the Dutch Government financed the Masterplan 2035 Project, which was completed by the end of 2013. This Masterplan states the strategy and direction towards sustainable development of the lowland, delta town Beira. It aims at a safe, prosperous and beautiful city.

The Masterplan addresses amongst others, urban stormwater as an urgent problem to tackle, as it causes serious urban flooding and soil erosion and poses a serious threat to infrastructure and human health and well-being. It is also anticipated that existing urban infrastructure will have to be improved and new infrastructure to be integrated in town expansion, which is needed to provide housing to the increasing population.

Greening of infrastructures (Green Infra) is such an innovative approach. It helps to solve the stormwater problem as greening of the urban environment increases the water retention capacity and it will reduce soil erosion. Both are excellent examples of services that nature (i.e. ecosystems) provides to humans for their well-being. These are generically called 'Ecosystem Services' (ES). Furthermore, green infrastructure enhances several additional ES in urban environments. The 'grey to green' transition has been successfully realized in practice in a few cities e.g. in the USA. Especially the city of Portland in the USA provides an outstanding case example. We are convinced that the advantages and potentials of green infra contribute to efficiently protect coastal cities, help them to adapt to the effects of climate change such as flooding and coastal erosion. It is our hypothesis that once the Beira stakeholders and policy makers at the national level and in Beira get fully informed of all the benefits to them, they will go for the transition i.e. towards green infrastructure as a realistic alternative to solely a grey infrastructure solution for solving their stormwater problems.

Recently, the City council of Beira had to make an urgent decision to guarantee land availability to increase the retention capacity of the drainage system of Beira and to avoid that new concessions are given out in the foreseen areas for the retention or lagoon area. The Beira Masterplan foresees the development of the existing wetlands east of Estrada Carlos Pereira (or Airport Road) as a retention area. This will increase the retention capacity with at least 150 hectares and enable the improvement of the drainage situation in Beira with particular emphasis on the eastern parts (Maraza and Chota). The problem of inundations in Chota

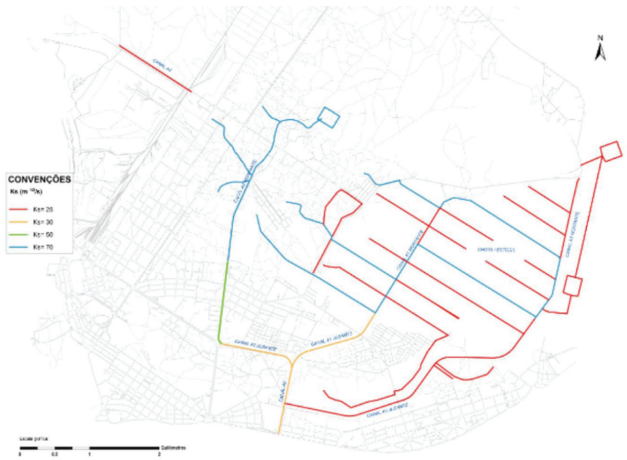


Figure 1. The current drainage system drains all the channels to the southern outlet at Palmeiras

is an annual problem caused by heavy rainfall in combination with an ill functioning drainage system. This problem is expected to increase due to growing urbanization. Many new houses are constructed in the area which increases the amount of storm water to be drained from the area and at the same time reduce the space to create retention capacity.

We – the Dutch team Deltares, Alterra, Witteveen+Bos and Wissing – offer in GreenInfra4Beira a set of innovative, complementary tools and approaches developed by us to facilitate local stakeholders in making this transition. Our tools and approaches combine ecosystem engineering (e.g. hydrological modeling of green infrastructure) with supporting stakeholder processes (e.g. using interactive maps in local meetings). These tools and approaches are necessary as such transition requests a new way of thinking among all involved stakeholders, and a strategic cooperation among stakeholders (e.g. the water and urban green department at the municipality) that conventionally do not work together to such extent.

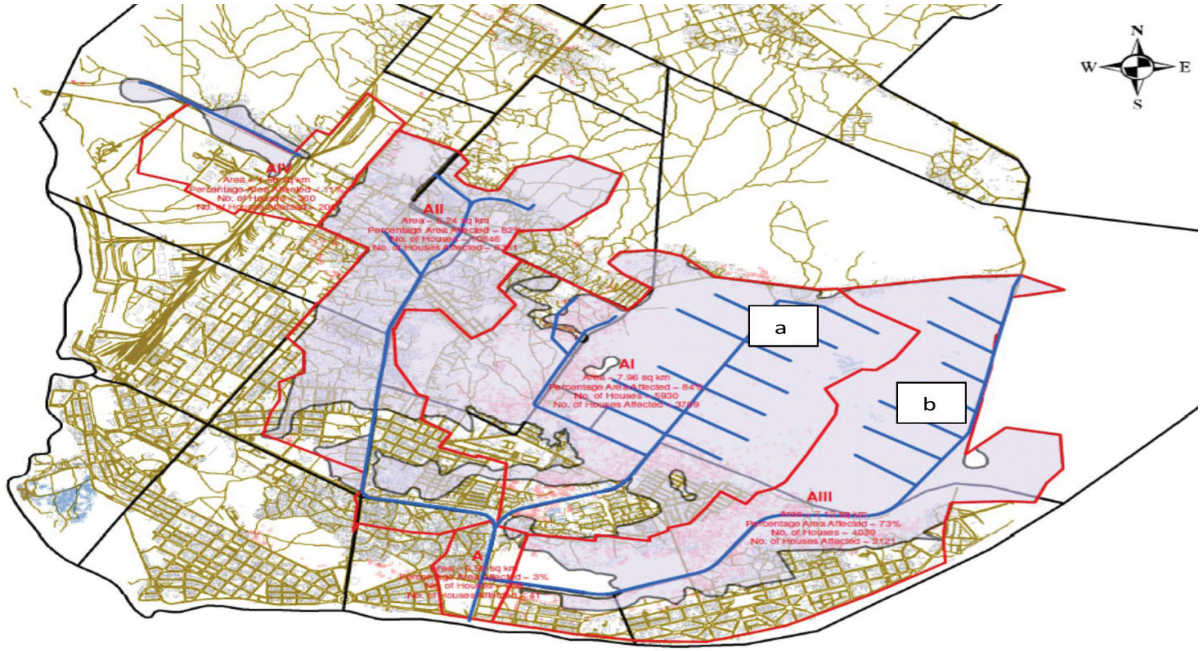


Figure 2. The once every 5 year flooded areas in Beira and the location our proposed pilot neighborhoods)a and b'

1.2 Goal of the project GreenInfra4Beira

The goal of this project is to develop a strong and resilient green infrastructure ES network for Chota. The GreenInfra4Beira project addresses issues of local water management and the availability of water and how optimum and attractive conditions can be created for the urban population, using green infrastructure.

Developing a strong and resilient green infrastructure in Chota involves examining, interpreting and building upon the inherent patterns in the landscape and coastal zone, in an effort to build sufficient capacity for regeneration. The green infra network will not only solve Chota's flooding problems, but will have additional merits (co-benefits) related to the natural and urban environment.
The high growth of the population of Beira and the ongoing fast urbanization of the currently open areas to the east of Beira will make it impossible to implement the proposed measures at a later stage in time. A total retention capacity of 150 hectares will be necessary to solve the inundation problems of Chota. Furthermore there is the need for a second outlet to improve the drainage system of the northeastern parts of Beira, and to lessen the pressure of the southern outlet at Palmeiras. During high tides that southern outlet cannot drain its water.
The city council is convinced that if no measures are taken now it will be too late. The important goal of the plan is a direct improvement of the

drainage system of the neighborhood of Chota and a staged improvement of the drainage system of the whole of Beira-east. Next to those important goals, the measures also have important co-benefits, for the planned urbanization, the urban infrastructure (roads and waterways), the growth of tourism and the improvement of the ecological systems in the low lying coastal areas of Chota and Muave.

The purpose of the project therefore is to create a sustainable living environment of Chota. Water management plays a key role in the sustainable future of Chota. There is the necessity of drainage and storage of rainwater as well as the provision of clean drinking water. The Green Infra for Beira plan will be a plan for implementing green infrastructure in the pilot area. It will be a plan ready for local policy makers to decide upon so that the next step can be the physical realization of green infrastructure in the way as designed in the plan.

Moreover, upscaling urban area development continues to be the drivers of economic and social development where strategic stakeholders and development partners are involved, including the World Bank.

Fig 1-1 pilot area: the neighbourhood Chota

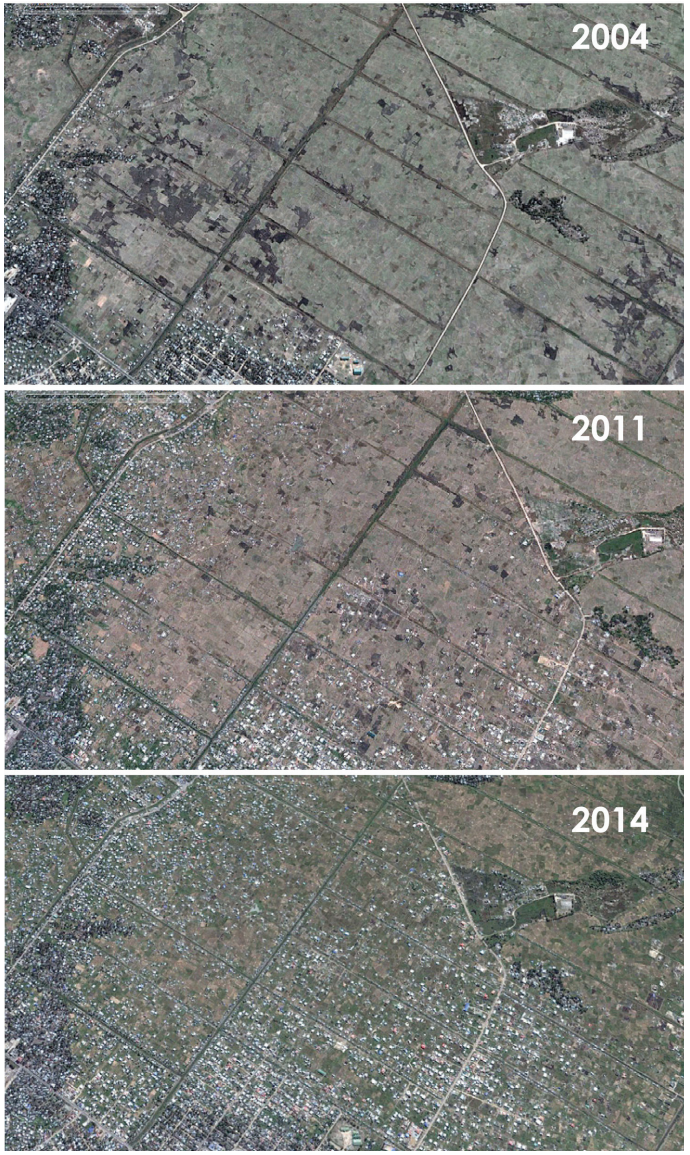
Figure 3: Study area, the neighbourhood of Chota in the northeastern district of Beira

1.4 Specific characteristics of the Chota area

Before the colonial period, the area that is now Chota, consisted of wetlands, marshes and several dunes. From the early 1960's, the marshlands were drained by canals and ditches and made suitable for agriculture. It is not precisely known if the channels were used for drainage only, or if they also had an irrigational function during drier periods. In the 1960's the characteristic systematic canalization of the rural 'polders' came into being. Ever since, the drained land was used for agriculture, and no urbanization was seen until the 21st century.

Figure 4. Beira as shown on a U.S. army map, 1965

Especially in the last decade, land use in Chota is changing dramatically. Images from google earth shows a great shift from agricultural fields into housing plots in just 10 years. Chota is allocated for a neighbourhood, expected with at least 84.000 inhabitants, given its surface of 667 hectares (667 x 25 units/hectare and a medium of 5 inh/unit). Because all of Chota is given in 'land concessions', this development will continue until the whole of Chota is urbanized. Considering the current speed, this process will be finished in 5 – 8 years, when Chota will be transformed from a manmade agricultural area into an urban quarter.



The google earth maps in figure 5 show many new houses. Green areas are trees or wetlands. White/yellow lines are roads. White/yellow areas are new sandy areas on the clay for house development. The straight dark line is the channel. Mosaic patterns of green/brown areas are rice fields. These observations are simplified in the physical appearance map (figure 6).

In the period 2010-2015 approximately half of Chota is used for agricultural purposes, mainly the cultivation of rice and sweet potato. The area is interspersed with some (elevated) sand ridges which are used for living and gardens and have a rich variety of land uses including a cemetery, industry, markets, hospital, park, living and gardens.

The physical appearance map plus the land use map combined results in a landscape unit map (figure 7). It is striking how much these maps follow the same patterns. For example that the land use agriculture was exactly on the clayey areas.

Figure 5. Chota on the Google Earth maps of 2004, 2011 and 2014

Figure 6. Chota - Physical appearance map

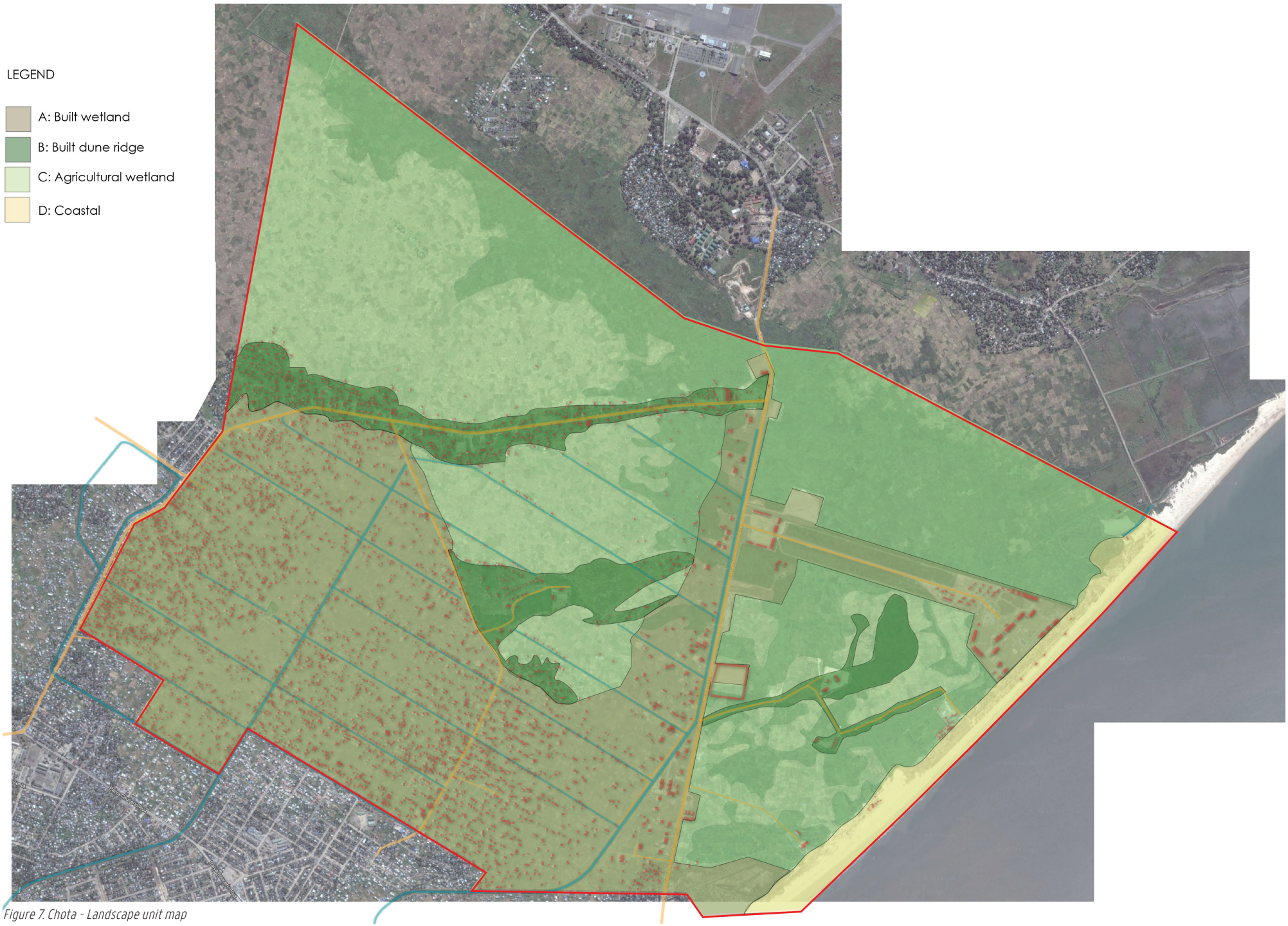


Figure 7. Chota - Landscape unit map

1.5 Design with local stakeholders

The key-objective of our proposed project GreenInfra4Beira is to enable local stakeholders to solve the stormwater problems in Beira by using green infrastructure as solution. Essential in our approach is that the project will be primarily executed by the key Beira stakeholders themselves. As stated above, we are offering a combination of complementary, innovative, Dutch developed tools and approaches to guide, and support their effort and thus assist them in achieving the key-objective. Furthermore, GreenInfra4Beira aims to provide a demonstration case and thus be a catalyst for other places in Beira, other cities in Mozambique – and far beyond – facing comparable problems to get aware of the benefits of, and thus go for green infrastructure solutions. Therefore, the second main deliverable will be a demonstration of the combined use of our innovative tools and approaches that facilitate local stakeholders in accepting and designing of green infrastructure to actually solve urban stormwater problems in their neighbourhood. Here we – i.e. the Dutch project team – see the key potential for scaling up: we see great potential to get involved in, and getting paid for guiding and supporting the stakeholders with help of our tools and approaches at other places in Beira, other cities in Mozambique and far beyond in designing and planning infrastructure solutions tailored to their specific desires and local possibilities.

1.6 Grey to Green; lessons learned from Portland

Some of the most advanced examples of green infrastructure solutions for swift infiltration of stormwater in an urban environment can be found in the City of Portland (United States of America). This is the reason why a study tour to Portland was part of the project activities with the idea that to see is to believe. Portland faces an average of 940 mm of rain falls annually. Soil and plants absorb rain in a natural environment. But when streets, buildings and parking lots cover the ground, rain can wash over the hard surfaces and carry dirt, oil and other pollutants to rivers and streams. This storm water runoff can also cause erosion and flooding that harms properties and wildlife habitat if it is not properly managed. Managing stormwater at its source where rain falls reduces the damage stormwater runoff can cause. Green infrastructure designs mimic natural systems that reduce peak stormwater runoff and improve water quality. While doing this it significantly reduces investment costs in sewers and traditional grey infrastructure.

Figure 8 shows the reduction of peak flows due to the wide scale introduction of green infrastructure and figure 9 shows the corresponding reduction in investments of grey infrastructure. Integrating green infrastructure into the build environment of Portland (see figure 9) provides ecosystem service benefits beyond just stormwater management.

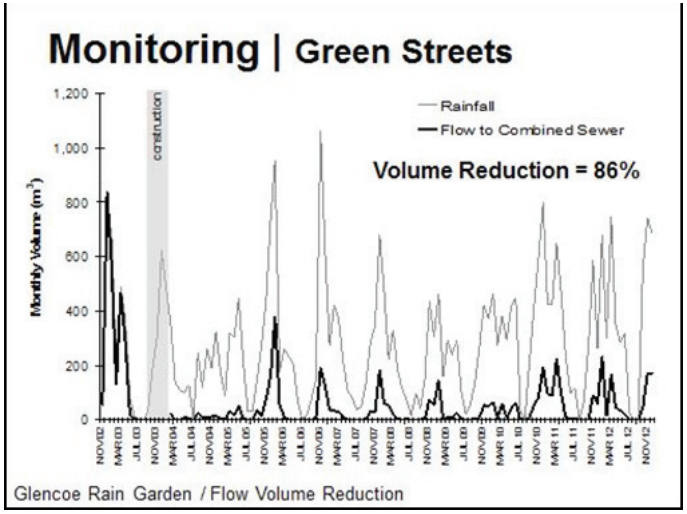


Figure 8. Portland, reduction of peak flows due to green infrastructure

The city of Portland states: "green infrastructure helps sustain a community's liveability, health, and economy. Bringing nature into the city can increase mental and physical health, enhance social interactions, increase property values, and reduce the demand for energy and piped infrastructure, which translates to cost savings" Apart from the lessons learned on the wide scale application of green infrastructure important lessons were learned that relate to the development and implemention of urban projects. The most important lessons are:

- Development is peoples work!
- Networking and long-term relationships as well as trust building are of vital importance.
- The importance of serendipity can not be under estimated
- Grab opportunities as they come
- Facilitate leadership and entrepreneurship and leave comfort zones
- Commitment (city development is not only about making profit ...)
- Beira's art-deco is an important inspirational factor and unique selling point: it is not exploited for the moment

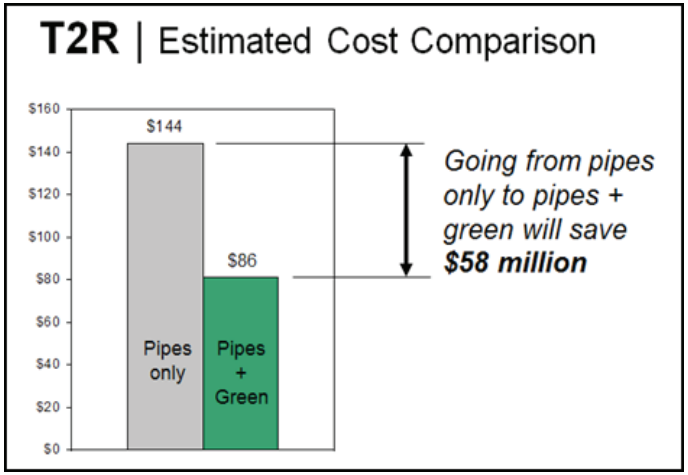


Figure 9. Estimated Cost Comparison

Fig.ure 10. Some green infrastructure examples in the City of Portland: stormwater planters (left) and green streets (right)

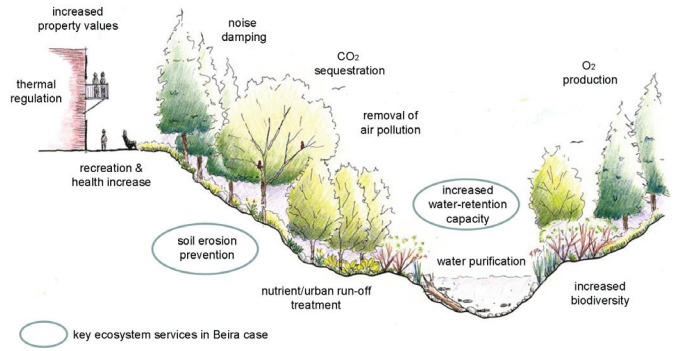


Figure 11 Green infra helps to solve the storm water problems by increased water retention. Examples of additional ecosystem benefist (ES) provided by urban green infra

Benefit	Benefit Category
Health	✓ Air quality improvement: Vegetation filters particulates and other pollutants from the air and thus improves air quality ✓ Increased 'greenness': Increasing greenness encourages more walking and other physical activity, has metal health benefits and reduces obesity and mortality rates
Energy and carbon sequestration	✓ Energy savings: Stormwater is kept out of the sewer system, so volume of waste water to be pumped and treated is reduced, which conserves energy and saves money. Furthermore, vegetation cools the air to reduce the urban heat island effect, so less energy consumed for air conditioning. ✓ Greenhouse gas reduction: Added benefit going with the above energy savings ✓ Carbon sequestration: Vegetation removes and stores carbon dioxide from the atmosphere, Removing invasive vegetation can also reduce decomposing organic matter, which releases carbon into the atmosphere.
Community livability	✓ Amenity/aesthetics improvements: Grey to green improves neighborhood aesthetics and increases property values. ✓ Community cohesion: Green spaces attract people, thus promoting contact among neighbors and some studies indicate that trees and vegetation are associated with lower crime rates. ✓ Access to nature: Grey to green increases public access to, and thus being able to enjoy green. ✓ Environmental quality: Grey to green projects in low income and minority neighborhoods can enhance environmental equity in a city.

Table 1 Addiional Grey to Green Benefits (source: City of Portland, claims are scientifically underpinned

1.7 Added value for Beira

The Masterplan is a means to realize a "safe, prosperous and beautiful Beira". GreenInfra4Beira contributes to the realization of this Beira ambition, i.e. makes it concrete, in practice, at neighbourhood scale. Principally GeenInfra4Beira aims to solve the stormwater problem thus resulting in less flooding's and hence increased safety. However, green infra results in several additional benefits that positively contribute to prosperity and to making the greened neighbourhood a (the) place to be! And if we can demonstrate it to work in one location in Beira, it may work in other Beira neighbourhoods as well.

That is why the key-local stakeholder – the mayor of Beira – would highly welcome to host and facilitate our demonstration project. His letter of support and commitment states (translated from Portuguese):

"Using green infrastructure to solve our stormwater problem sounds like an innovative and very attractive solution to us. It is attractive as it has the potential to solve more then only this grant challenge (i.e. stormwater). The co-benefits of green infrastructure – or 'ecosystem services' as you call them – may also contribute to solving some of our other problems. In this way GreenInfra4Beira has the potential to contribute significantly to the realization, in practice of each of the three elements in our ambition. As such this project is exactly the kind of project we have in mind for operationalization of our Masterplan! Therefore, it would be a great pleasure to me and my team to welcome, host and facilitate this project if it will be granted to you by 'Partners for Water'. In every which way we can."

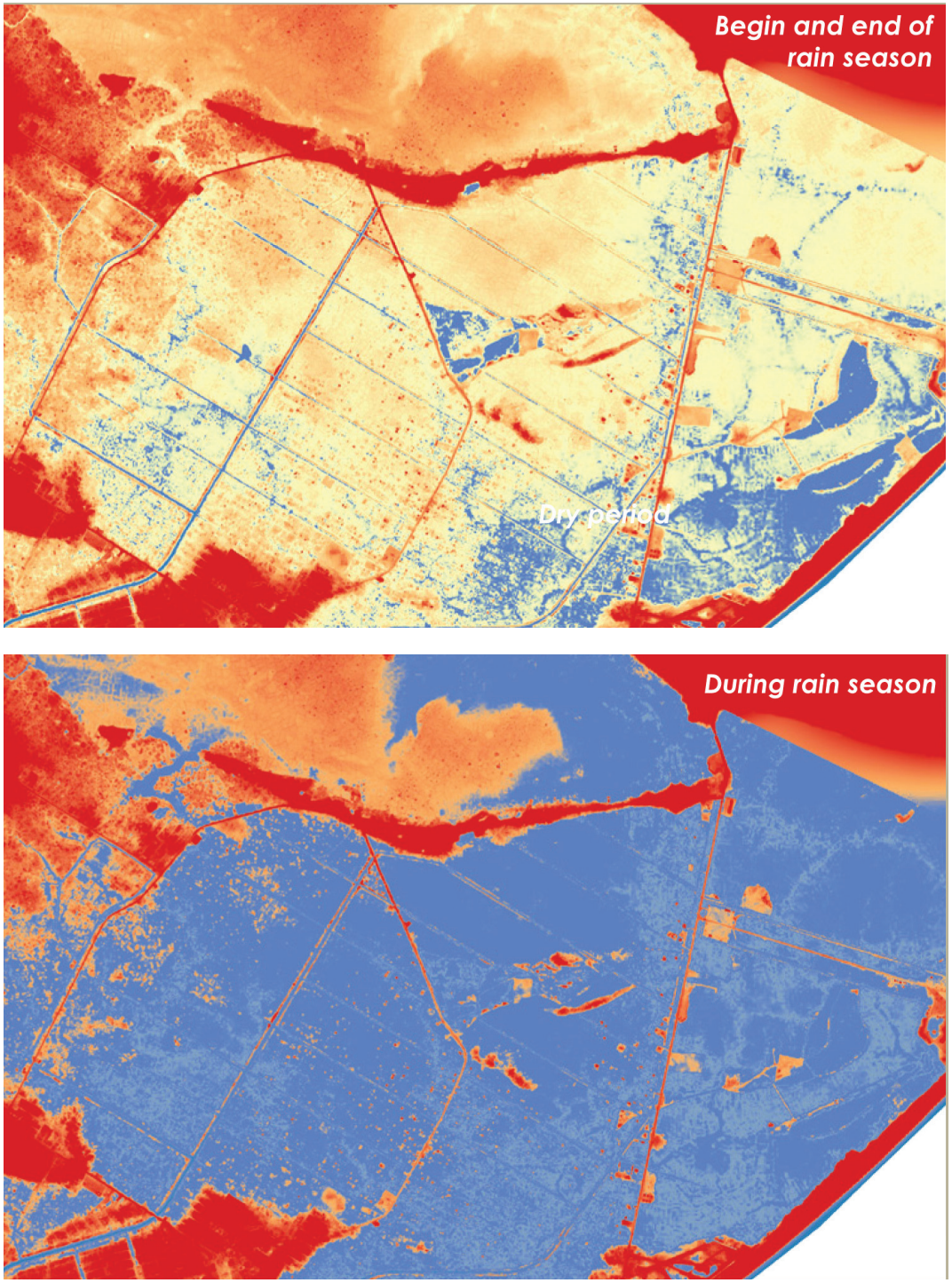


Figure 12. Degree of flooding in different seasons based on the height map of Beira (Lidar Neelen en Schuurmans)
Above: Situation at the end of the dry season
Below: The worst case situation

2 Definition of the problems in Chota

2.1 Water issues in Mozambique

Mozambique as a low lying delta country is faced with many water related challenges of which the following are important in the context of Green-Infra4Beira: Main issues are restrictions in financial budget and lack of knowledge. This results in:

- Limited human and institutional capacity, resulting in underperforming (water) institutions. Water institutions lack institutional clarity and/or power and don't have sufficiently trained staff to perform all their tasks. This particularly applies for urban water management and related institutions;
- Limited inter-sectorial cooperation and coordination. The various ministries and agencies dealing with water issues do not cooperate effectively, and coordination between the sectors is poor. This impedes integrated and cost-effective solutions for complex problems;
- Limited Integrated Water Resources Management (IWRM) application. The IWRM principles are either not implemented or hindered by existing structures (and poor inter-sectorial cooperation (see before);
- Insufficient cooperation and coordination. Long-term strategic planning of land and water resources is obstructed by poor or non-existing trans-boundary planning. Ineffective operational water management hinders effective flood prevention and mitigation strategies;
- Market illiteracy. There is limited interest from the private sector to develop initiatives in the water sector and the enabling environment is rather restrictive;
- Political will/policy implementation for cost recovery. The Government is hesitant to raise water fees and harmonize prices towards a cost-recovering price structure for water services, which often results in financially unsustainable water institutions;
- Poor access to finances / credit, which results in low investments. The high interest rate (almost 30%) is one of the constraints;
- Poor law enforcement, which often results in lack of planning and/or insufficient financial revenues;
- Insufficient long-term planning. Ad-hoc versus pro-active. Although strategies have been developed in some cases, tendency is to look for short term issues and not to follow the longer term processes and recommendations. A good example is that urban plans are not adhered to and that municipalities provide concessions and building right without technical criteria.

2.2 Water issues in Beira

Beira is located in the Delta of the Pungue River, where the Pungue River meets the Indian Ocean (see Figure 3). The city is facing several challenges. First, economic growth and population growth have a direct impact on the city. The city is growing fast, resulting in substantial demand for (newly reclaimed) land. However, urban development is poorly regulated and settlements in flood prone areas and without basic infrastructure are common. More suitable land is needed for industrial purposes, for new and improved housing and public facilities.

Central Beira can be characterized as a flat plain bordered by a coastal ridge. There is limited natural drainage of the area to Rio Macuti in the East and to Rio Chiveve in the West. The majority of the city is built on naturally marshy land.
This natural drainage has been augmented by the construction of storm water channels and pipes. These systems make up approximately 81 km of pipes and 33 km of channels. Piped storm water infrastructure only exists in the formal areas of Beira. The piped and open channels systems collect storm water to a primary drainage system that discharges directly to the sea. The drainage of swamps in the northern part is connected to the primary channels as well. Between the neighbourhoods of the urban areas, there are unsettled areas subject to flooding. All these systems have serious problems. Some of the causes are:

- Natural causes including high rainfall intensity (stormwater), flat topography in some areas, and poor infiltration;
- Man-made causes, such as undersized culverts; poor maintenance operations; underdevelopment of tertiary drainage facilities; and encroachment on the right-of-way of primary and secondary channels;
- Developments taking place in low-lying areas prone to flooding which are not suitable for development.

It has been analysed by the Masterplan study Beira 2035 that to prevent flooding additional storage capacity needs to be created for the alleviation of the primary drainage infrastructure during high tides and intensive rainfall. Two retention basins of 50 ha each would be sufficient but it turned out that there is no space left for these retention basins. Therefore there is the need to develop other solutions through green infrastructure planning.

2.3 Water issues in Chota

The drainage system in Chota consists of three large drainage canals (canals AI, AII and AIII) that run from the northern parts of Chota towards the outlet in Palmeiras. Canal AI runs from the northwest (Mananga-Esturo area), Canal AII from the central areas (Matacuane-central Chota) and Canal AIII from the north-eastern area. From these canals, a series of smaller drains flow in east - west direction. In the present situation large parts of Chota suffer from flooding problems. These inundations occur every year and can take several weeks or months. Apart from causing inconvenience for the inhabitants, it also has serious effects such as;

- damage of the infrastructure (roads, crops, houses and the belongings of the inhabitants);
- water quality and sanitation problems (as a result of inundated septic tanks)
- human health issues; malaria and in some cases cholera. At the lowest points in Chota the water remains for several months. These circumstances are ideal for mosquitos. As a result malaria is a serious problem in the area;
- public danger; illegal construction is a public danger, it can hurt people, infrastructure and property.

During field visits it was observed that the flow in many of the canals in Chota is obstructed due to the presence of vegetation, causing a significant reduction of the discharge capacity. Also, many blockages such as illegal constructions and land fillings are present. In some cases culverts have been used to pass the land fillings but the dimensions of these culverts are limited and the culverts reduce the discharge capacity. Finally the ongoing urbanization causes a faster runoff from rainfall. As a result the flows in the canals and culverts increase. At the moment the capacity of the drains is not sufficient to deal with these volumes. Summarized: the present drainage system of Chota is insufficient and further urbanization and development will make the situation even worse.

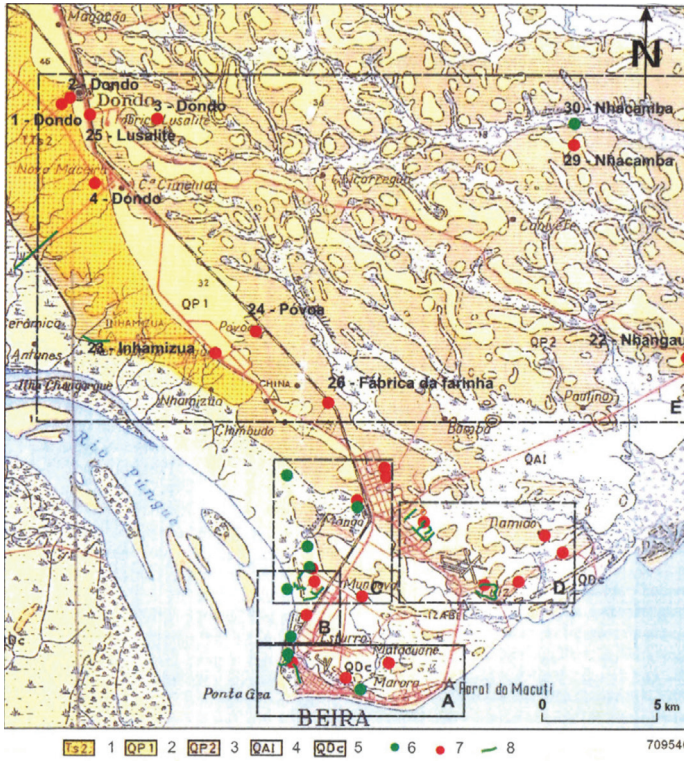
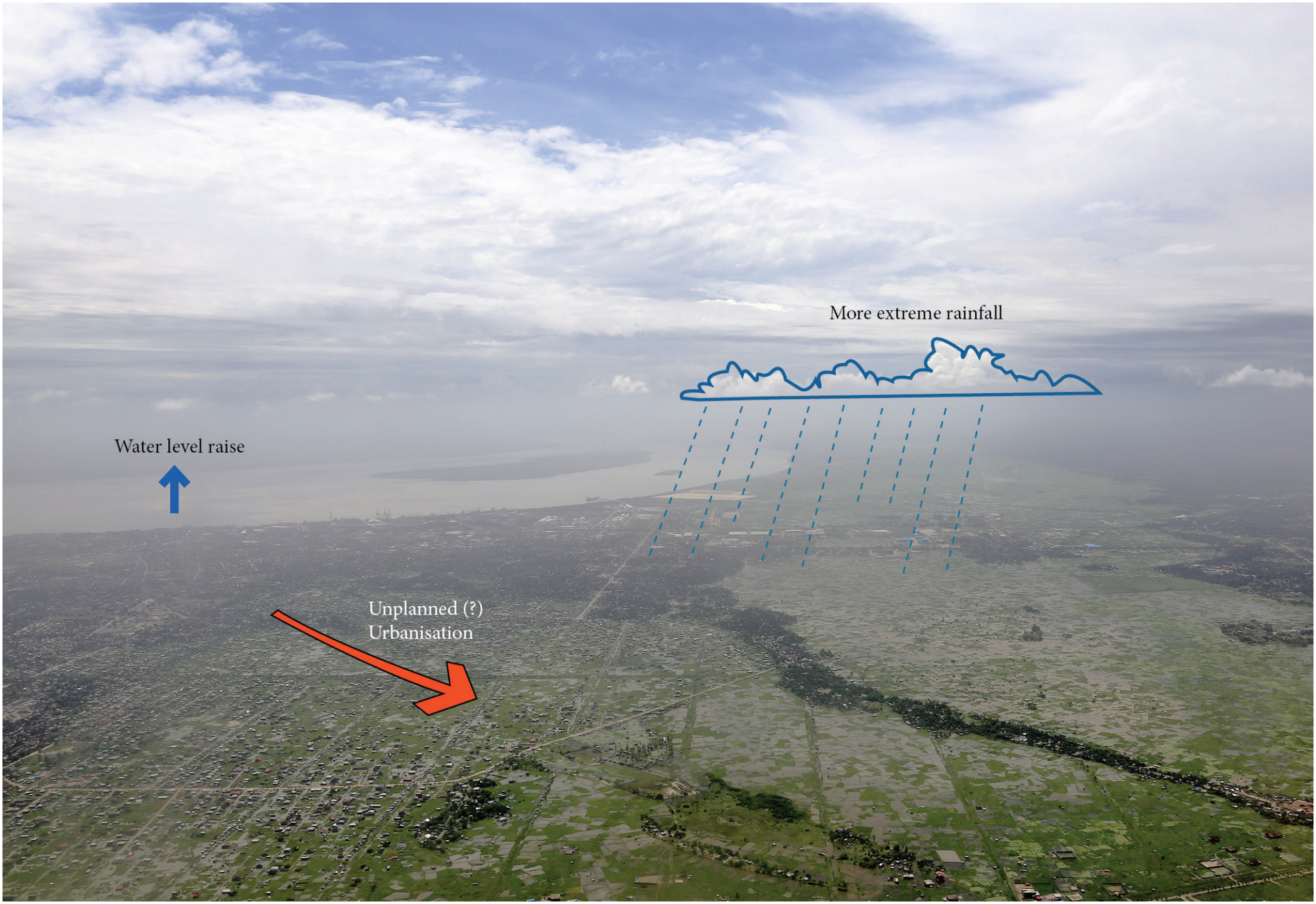


Figure 13. The pattern of soils in and around Beira

Figure 14. Rain during the dry season


More extreme rainfall
Water level raise
Unplanned (?)
Urbanisation

The drainage system of Chota is not an isolated system. The main share of water flows to the Palmeiras outlet. In the present situation water from Maraza is also flowing into Chota and the water system of Chota interacts with the water system at the other side of the Airport Road. Measures taken in Chota will improve the Beira drainage system as a whole. Calculations by Portuguese company TPF Planege and Deltares (Adri Verwey) show the required measures in the primary drainage system. The most important conclusions are:

1. the capacity of the Palmeiras outlet is not sufficient for the present situation. A second outlet for the northern part of Chota is advised. The location of this outlet, near Rio Maria has to be selected carefully to prevent problems as sedimentation and damage by coastal erosion.
2. in low-lying flat areas it is not possible to drain all water directly to the sea. During storm water events retention of water is needed to reduce the peak flows in the canals, culverts and outlets. Calculations of the drainage system show that approx. 150 ha of retention area is needed. This area serves a catchment area of 1.250 ha (Chota and Maraza).

In the flat areas of Chota and Maraza, the discharge capacity of canals and culverts cannot be adjusted to peak discharges. The old drainage system of Chota was designed for agricultural land use. To prevent flooding in urban areas, where run off from rainfall is much faster, additional retention capacity is required. In November 2014 the City council approved a set of green infrastructure measures to improve the Chota drainage system. However it was concluded that it is not possible to implement all required retention capacity to deal with a storm water event with a 10 year return period. Only around 60% of the required 1 million m3 water retention could be planned for. Due to rapid urbanization during the last years the total required retention area cannot be accommodated anymore. This clearly shows the urgency to take action and measures: every month the available area for water retention decreases.

The severity of flooding in Chota

The floods occur mainly in the rain season, which starts in November and ends in April/May (Figure 15). This is also the time that people indicate floods, with the worst flooding in January and February. After the rain season the water slowly dries up but large parts remain wet over a long period of time in the lower places. In June, there are still a lot of ponds, while in July many will disappear. However in large parts of Chota it will never become completely dry because water doesn't infiltrate easily in the areas of clay.

In Chota flooding usually occurs in a severe way. According to the residents, the whole of Chota is undergoing floods in a more or less severe way. The only exception are the higher grounds on the sand ridges with a relatively higher altitude. Because of ongoing urbanization, new houses are being built in the lowest and wettest areas, the lowest of which seems to be the sand pits. Originally these depressions were sand dunes in the floodplain. During the era of the colonial urbanization of neighbourhoods like Matacuane, Macurungo and Macuti, the dunes were used as sand pits. When we analysed the relationship between flooding and the geography of the landscape, it appears that flooding occurs first and foremost on lower lying clay areas (figure 16. Although in most areas the average flooding is 30-50 cm, some residents indicate the height of the water into their house at a level of 120 cm. It is the most recent developments in the clay areas where people suffer the most, opposite to the oldest settlements on the higher sand ridges.

The local impact of flooding

Although some houses have somewhat elevated floors and remain dry most of the time, other houses get regularly flooded inside as well. Even with a population adapted to this situation, damages occur, e.g. to electric appliances, and the nuisance is considerable. Other than problems towards housing, infrastructure and services, flooding also causes serious problems to public health. Probably the most serious of those are water born diseases such as malaria, cholera and diarrhoea, as stormwater and floodwater mixes with sewage. The stagnant water is a breeding place for mosquitos and mortality due to malaria is high in this area. From a social and economic perspective flooding causes problems such as crop damage, road damage and potential danger from electricity.

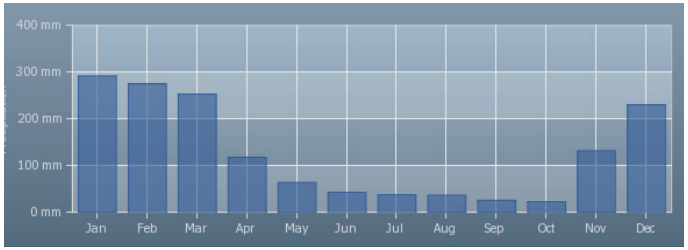


Figure 15. Average precipitation in Beira, 2013 (www.weather-and-climate.com)

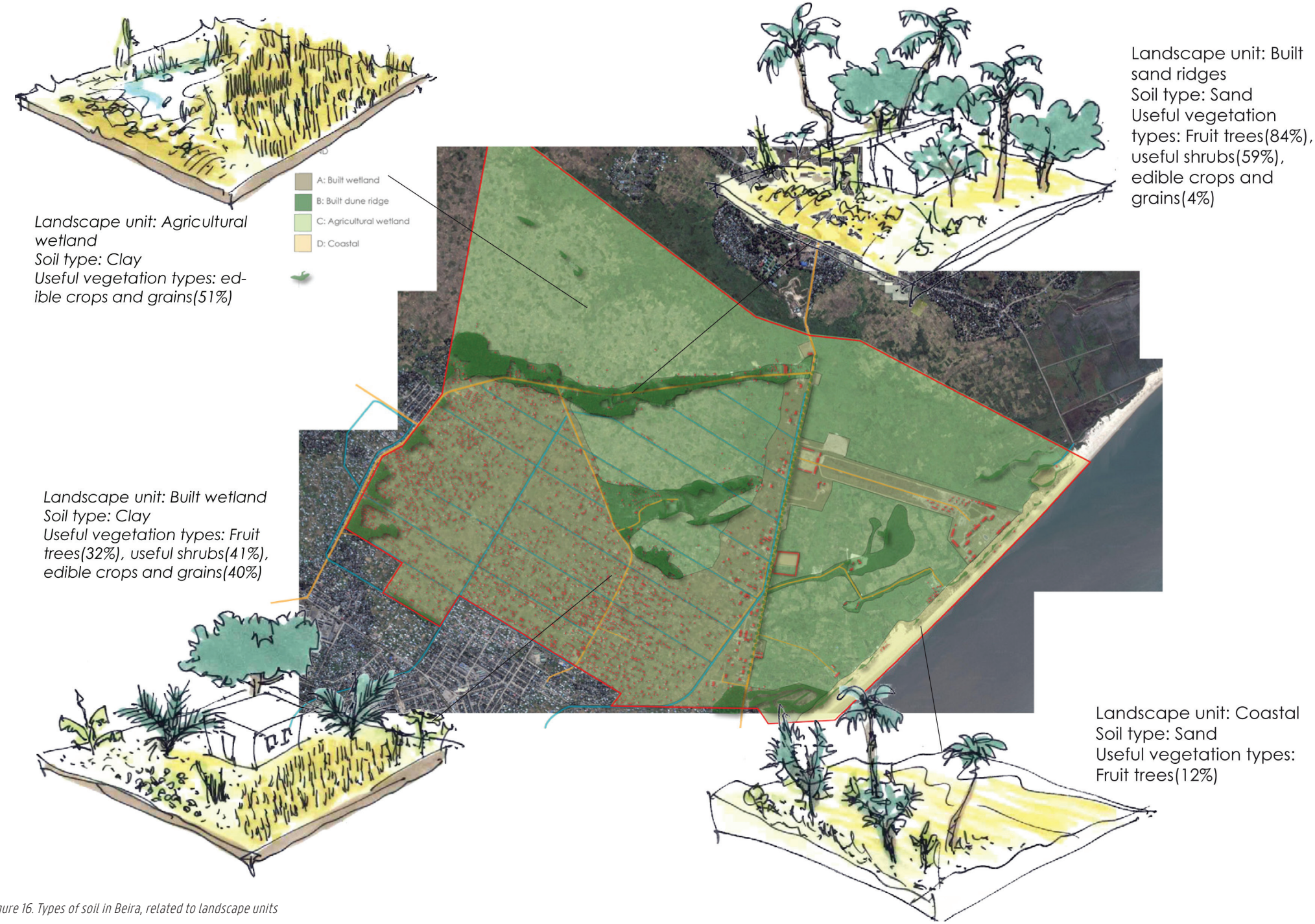


Figure 16. Types of soil in Beira, related to landscape units

During meetings, the need to reduce the occurrence of malaria infections was emphasized. Malaria is a major problem in Mozambique. According to WMO: "In Mozambique, malaria is a major cause of morbidity and mortality, especially among children. The disease represents around 45% of all cases in outpatient visits, approximately 56% of inpatient at paediatric clinics and around 26% of all hospital deaths". Although problems are less in urban areas, Beira is an exception, as in the low lying parts of the city much rain water remains stagnant for long periods. For this reason, mosquitoes have a high probability of reproduction. The risk of malaria is one of the principal reasons for the need to improve the drainage situation in Beira.

The causes of flooding

Currently the low-lying Chota area lacks appropriate drainage during the rainy season. Several days in succession and various times a year, water remains stagnant around houses. Chota is among the lowest parts of Beira. A specific problem of the Chota water system is the fact that just north of the currently (2015) inhabited areas, there are the wetlands between Chota and Manga. Because of the fact that water in these wetlands cannot be drained properly it flows to the lowest parts of Chota. So the drainage problems of Chota are not only caused by Chota's own stormwater, but also water from surrounding areas flow into Chota.

Especially during the rain season Chota has a lot of water to process. Our analysis shows that for the major part, both the floodplain and the hinterland currently show a lack of proper storm water management, resulting in heavy flooding of flat areas in the city and the floodplain during the rainy season. Especially the low-lying Chota area lacks appropriate drainage. Several days in succession and various times a year, water remains stagnant in the streets, the plots and houses. In Chota even the cemetery is flooded regularly, which we expect may cause a serious risk to health. In the lowlands, there are natural or man-made depressions that retain water even longer, possibly for month.

Figure 17 June: water remains in the lower areas after a flooding

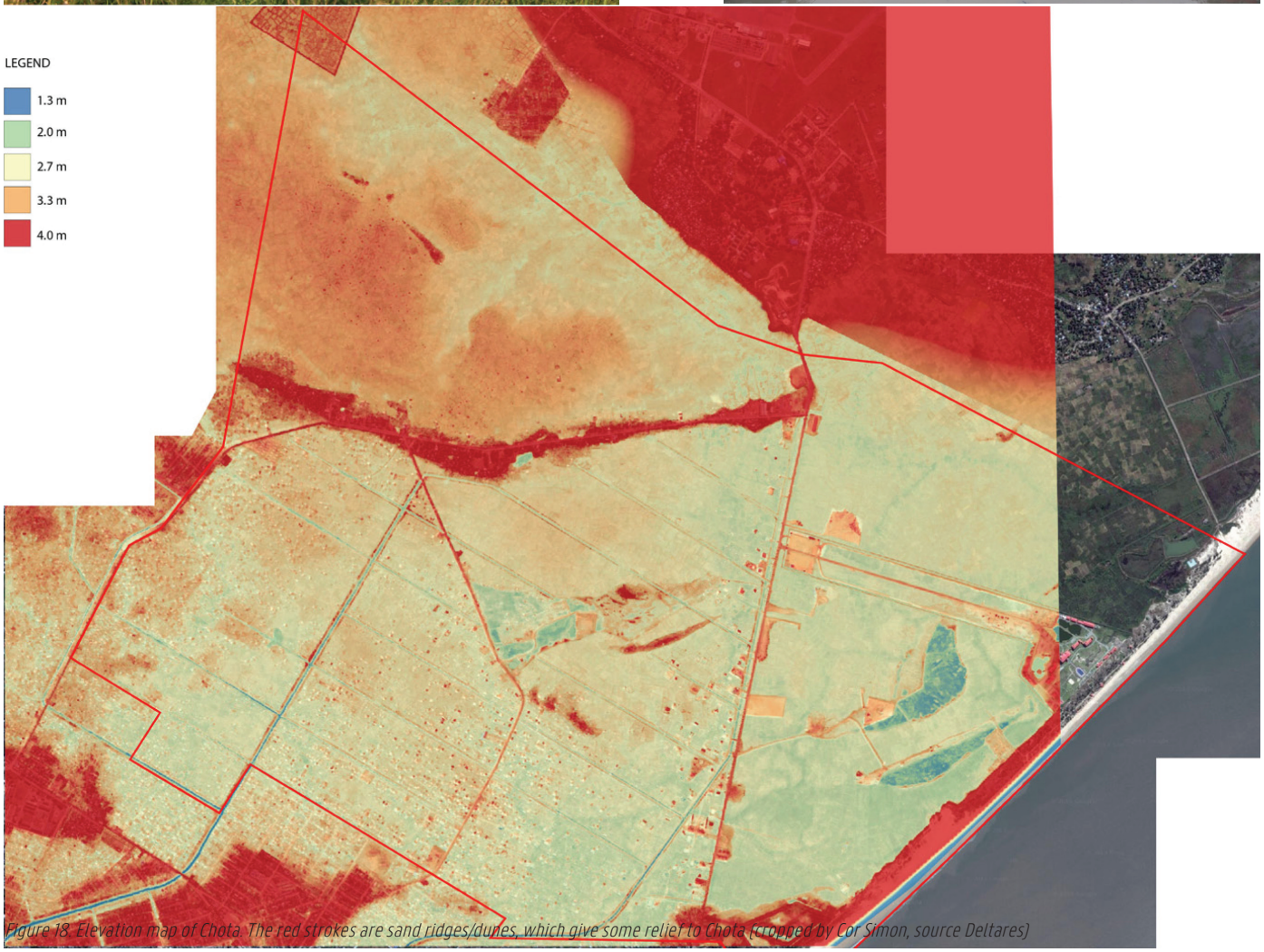


Figure 18. Elevation map of Chota. The red strokes are sand ridges/dunes, which give some relief to Chota (cropped by Cor Simon, source Deltares)

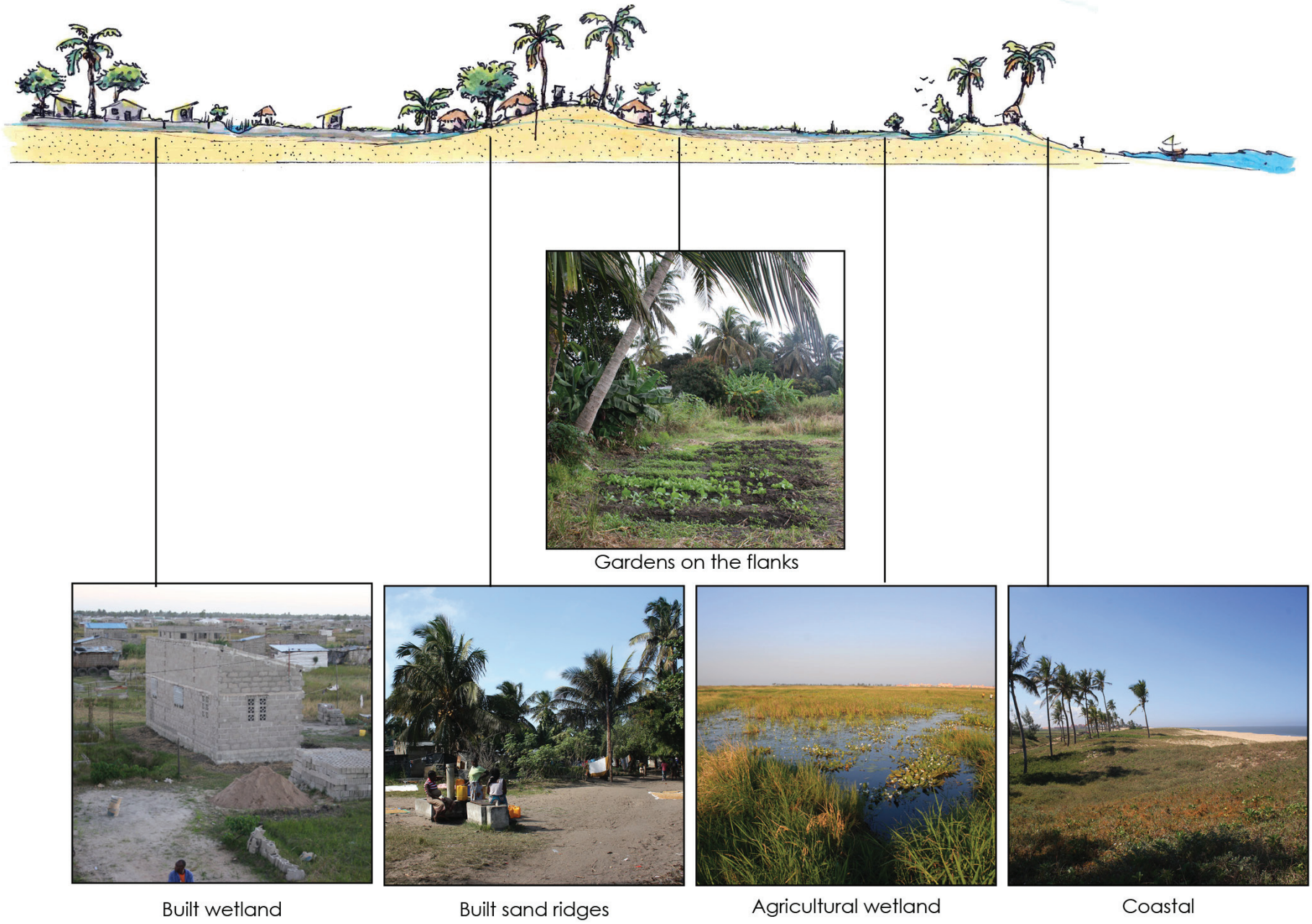


Figure 19. Schema of the elevation in Chota, related to the characteristics of the landscape

The current state of the main channels AI, AII and AIII
The main channels were constructed by the Portuguese with the purpose of draining the agricultural polders. It is not surprising that they lack the capacity to drain the urban areas that grew in the place of the agricultural areas. Poor maintenance and reed overgrowth reduces their capacity even further and especially in the last two years, people narrow the channels or blocking them completely in order to be able to build or reach their plots.

The Advantages of water
Water is essential for the local community. Part of the stagnant water infiltrates into the soil and replenishes the ground-water reserves. Currently, one finds mango and other fruit trees, eucalyptus and people grow some vegetables. This vegetation has a value to the daily life of the population and depends on water. Rice cultivation is on the retreat as the density of urbanization increases continuously. Rice farming has moved to other locations. e.g. north of Chota and east of the Beira-Dondo road, areas which so far have not been urbanized.
There is a shortage of fresh water in the (semi-) dry season. Many wells are under exploitation, having depths of up to 50 m. However, over the past years the water level in the wells dropped substantially and the salinity of this water increased.

Existing Green infrastructure of Beira
GreenInfra4Beira proposes an integral approach for Chota's water issues, by introducing a system of 'Green Infrastructure' measures that can be taken into account. That does not mean however, that currently there are no green infrastructural elements in Chota. The urban green infrastructure of Beira in general is diverse in terms of species with natural biotopes (from forest, shrub lands, grasslands and swamp vegetation). Urban green is omnipresent in the city parks, along the rivers and canals, accompanying the roads or on the plots, while large parts of the peri-urban areas are still in use for agricultural purposes.

2.4 Study of the Rehabilitation of the Storm Water Drainage System

There are other projects dealing with water management in Beira. The most important of these, is the Feasibility Study, Detailed Engineering Design and Construction Supervision of the Rehabilitation of the Storm Water Drainage System of the City of Beira (TPF Planege). This project focuses on the further development and rehabilitation of the primary and secondary drainage system of Beira and includes parts of Chota.
The Detailed Design of this project is currently being completed by TPF Planege and focuses on a substantial improvement of the drainage conditions of the districts Maraza, Mananga and Munhava and a partial improvement of drainage conditions in the districts Matacuane, Chota, Macurungo and Macuti. The project only provides primary and secondary drainage infrastructure. The tertiary system will remain the responsibility of coordination by the District Municipal Representatives. This is also the case for Chota, so one of the components of the GreenInfra4Beira project should be the focus on solving local drainage problems by investigating various aspects of the development of the tertiary drainage system.

The Detailed Design follows a phase of study where the integrated drainage system for Beira has been investigated for the whole area delimited by the Beira – Dondo road, the southern limit of the airport, the Indian Ocean Coast and Rio Pungue. It includes the southern branch of Rio Maria. Principal components of this drainage solution are the tidal outlet at Palmeiras, a retention basin at Maraza and the retention basin (lagoon) at Chota-Estoril, with the primary drainage channels connecting these components. The detailed design only comprises the rehabilitation of the tidal outlet at Palmeiras and the newly constructed retention basin at Maraza with their connecting canals.

Currently there is a high amount of water flowing to Chota from neighbouring areas, mainly from Maraza and Manga Mascarenha. In order to keep this 'external' water outside, the drainage infrastructure of Maraza has to be improved. With the planned short term drainage infrastructure improvement, the drainage conditions for Chota will improve slightly under low and average tide conditions, compared with the current situation. For 10 to 15% of the time the drainage condition will get slightly worse at the coincidence of extreme rainfall and high tide peaks at Palmeiras. The longer term and integral solution for the complete area of Chota requires

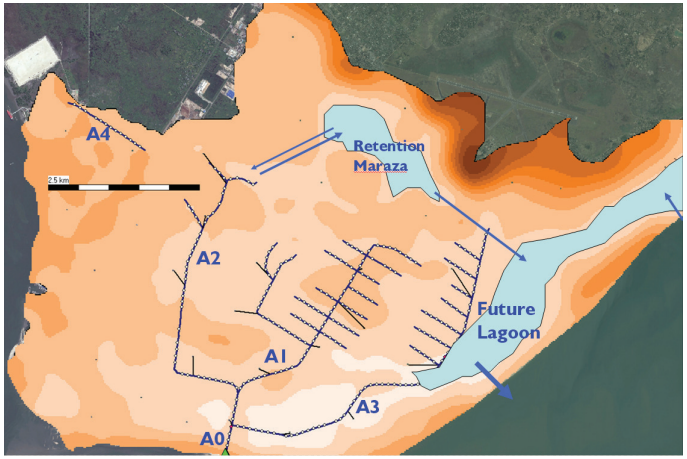


Figure 20. Proposal for retention facilities in Maraza and Chota-Estoril

retention facilities in Maraza as well as Chota-Estoril and connecting canals in the north-eastern part of Chota.

TPF Planege made simulations for this solution and showed that the run-off to the future lagoon at Chota-Estoril amounts to 0.75 Mm3, for a 1 in 10 year storm event, including climate change impacts. This would lead to a 75 cm increase in level for a 100 ha (1 km2) lagoon size, if runoff would be blocked due to high tides at the ocean. TPF Planege has not investigated connections to the ocean and made simulations only for a closed basin, subject to a single storm event.
The integrated drainage plan drafted by TPF Planege does not show the connection between Maraza Basin and the future Chota-Estoril Basin, although provisions have been made for this in the detailed design of the Maraza Basin.
It should be noted that for such flat area it would be logic to provide more connections between the various primary drainage canals in order to optimize the discharge capacity of the system over the complete area.
The design of figure 21 reflects the Portuguese way of designing drainage systems in terms of uni-directional flow systems, whereas the Dutch would design such flat systems based upon a concept of multi-directional flows in looped networks.

	T=2	T=5	T=10	T=20	T=25
	area [ha] (%)	area [ha] (%)	area [ha] (%)	area [ha] (%)	area [ha] (%)
area needed					
ha	4.7	7.1	8.8	10.6	11.1
%	11.9	18.0	22.5	27.1	28.4
duration rainfall event	9	14	16	19	24

Table Surface area needed for storage

Figure 21. Integrated drainage plan for Beira studied by TPF Planege

2.5 Deterioration of the ecosystem

Deterioration of the Beira ecosystem and its deteriorating potential for the local economy, coastal protection, liveability and health.

For thousands of years the interplay between river, sea and storm water has created a delta landscape characterized by a small sandy beach and dune area zone with a hinterland of low-lying swamps and creeks on clay soil. Occasionally, remnants of old dunes are present in this hinterland. In the areas under tidal influence (creeks, estuaries) mangroves are present. Mangroves are important for coastal protection, because the vegetation breaks the coastal tide, slowing down velocity of the water, stimulating silting up, roots fixating new soils and contributing to new land over time.

With climate change and sea level rise this is increasingly important.
The mangroves have a typical wildlife community of mudskippers, fiddler crabs and accompanying birds of brackish and salt water. Mangroves act as nurseries for the ocean wildlife. Numerous marine fish species, including sharks and rays benefit from these protective estuaries. In the swamps further landward extensive reed lands are present, a vegetation resulting from the high dynamics in rainwater abundance (from extreme flooding to drought). These reed lands are Eldorado's for waders and other reed birds, like the eye-catching Red Bishops (Euplectes orix). Altogether, this delta ecosystem offers specific abiotic conditions that support a variety of habitats close to one another.
As such, in earlier times the Pungwe estuary used to be a biodiversity hotspot like many other estuaries worldwide. Elsewhere such biodiversity hotspots attract thousands of rich tourists spending money on site seeing with field guides, boat trips, overnight stays in hotels and enjoying the local produce, handicrafts and hospitality. Without protection the potential to develop the tourist sector and accompanying jobs and foreign currency is foregone.

Besides these economic possibilities, the high biodiversity is essential for decomposition of water pollution, as is increasingly demonstrated by scientific research. With growing population and limited levels of sanitation and waste collection in the Beira areas, these natural qualities can provide some reduction of pollution levels. Especially in the swamps and other water bodies this biodiversity ecosystem services can help reduce risk of malicious smell and disease.

Early twentieth century, the city of Beira started as a small settlement, concentrated on the higher lying dune area. The low-lying clay swamps were step by step cultivated for agricultural purposes (e.g. rice fields). As a result the dune wildlife was the first community life to get impacted, followed by the mangrove and swamp ecosystem. Not all species suffered equally under the land transformation. Species like the cattle egret and other wader birds easily adapted, while others simply vanish. When several decades later, Beira really expanded into the low-lying clay areas, the impact on the ecosystem became more drastic. Water pollution, drainage, land use intensification, increased the dependence on and collection of natural resources. Mangrove over-exploitation for fire wood, fishing etc. were the result of the expanding city. These ecosystem threats are still ongoing, and the impacts can be seen in the current setting. There are huge differences between the biodiversity levels in the urbanized areas (e.g. residential areas of Chota), the agricultural land and the remnants of the original ecosystem like for instance near the Rio Maria.

Interviews with residents in the Chota district and site observations in the residential areas by Alterra Wageningen UR provided better insight in the degree of dependence of the local residents on the ecoystems and their services. Measuring revealed a decrease of the water level in the wells dug for drinking water in the previous century. The groundwater table is becoming salt. Though for drinking this is no longer a sufficient reliable source, for small holder irrigation this was useful. Now the brackish water can only be used for resistant fruit species. Especially for the low income population such small means of supplementing the diet with trees and vegetables grown on site are very important. In addition staple food such as rice is produced in the swamps in and around the urbanized areas. Of course the health implications of malaria due to the stagnant water in the rice fields are a serious point of concern. Besides that lack of affordable food is harmful as well.

In the dry season the local people are facing drought and difficulties of irrigating food crops. Along the benches and around the house lower income groups like to grow crops (tomatoes, salad, etc.) for selling these at the market or along the street and for own consumption. At the level of the small compounds also heat and wind are found problematic. These are concern to consider in the development of drainage, building sites and new urban areas for the lower income segment of the urban population.
When the urban land use will become more and more dominant, we foresee an irreversible collapse of the plant and animal community leading to the need of much higher costs of coastal protection, purification, etc. than needed for the development of proper urban natural resource management and exploitation plans. Only with careful planning and management urban development can make use of the ecological values and related services while preserving them for the future. Especially lower income groups are most vulnerable to degradation of ecosystems, as stated in the Millenium Ecosystem Assessment. With a growing population, quality of life for also the large group of low income residents is an important condition for social stability.

3 The GreenInfra4Chota

3.1 Situation after the implementation of the 2014 drainage improvements

The improvements in the drainage system as initiated by TPF Planege and discussed in the workshops in Chota, will improve drainage through the primary and secondary drainage canals, in particular the part around primary drainage channel A1. The improvement of the Palmeiras outlet will facilitate drainage through canal A1 during periods of medium and low tides. However, during high peak tides, the gate to be re-installed in canal A1 will be closed and delay drainage towards Palmeiras. Under these conditions, occurring around 10 to 15 % of the time, the drainage conditions will deteriorate.

For the northern and eastern part of Beira, improvements in drainage congestion will only be possible after the realization of the Phase 2 component of the World Bank financed Beira drainage improvement project, including the Chota-Estoril lagoon. As shown in the figure 27, this includes the rehabilitation of the primary and secondary canals. For the southern part of Chota it will be worthwhile to investigate the positive impact of the construction and maintenance of tertiary drains, which, in the vision of Beira Municipality, is the responsibility of local districts.

Only through a combination of designing a Green Infrastructure in Chota with the constructing a large retention basin (a lagoon) in Chota-Estoril it becomes possible to fully solve Chota's water problems in a lasting manner. We calculated that a Green Infrastructure can contribute to around 60% of solving Chota's flooding problems. The other 40% has to be solved by creating a retention basin in the eastern part of Chota.

In this chapter we will first describe the contours of designing a green infrastructure for Chota. Second we will describe the structural design that is the result of the workshops during the third mission (November 2014).

3.2 The contours of the Green Infrastructure

In order to be able to design a green infrastructure network for the Chota area, we first have to determine the design benchmarks, which are the following

- Hydrology: a long term solution for water related problems such as flooding becomes only possible when each area contains the storm-water within its own borders as long as possible. Water that flows into Chota from other neighbourhoods (e.g. Maraza) should be averted. But also within Chota there should be sufficient space to contain Chota's own stormwater. As well as a cohesive system of measures to store stormwater and when needed to drain through dedicated channels
- Hydrology: water is also a source of life and it should be stored to be used in the dry season for irrigation purposes. Stormwater can be seen as a basic resource for Ecosystem Services (ES)
- Living conditions: when the threat of water is contained by an integral system of measures, we will be able to design a save, healthy and beautiful urban environment in which it is pleasant and prosperous to live in. A green environment can help, as it offers opportunities for local food production, shade and better sanitary conditions.

With these 3 important benchmarks as the basic design layer, we defined the necessary goals and measures for Chota's green infrastructure. In general we find it important to:

1. Reduce the flooding problems in Chota by creating sufficient retention capacity for storm water. For reducing flooding one might expect that it is a wise decision to discharge water as soon as possible. But in order to use rainwater and raise the amount of fresh water we want to store rainwater. Also stormwater helps to improve the general water quality as it is mixed with untreated household water.

2. To determine specific measures that can be applied in improving the water system. For this purpose we designed an cohesive network of measures constituting the Chota Green Infrastructure.

The abovementioned two specific goals for Chota's water management correspond with the overall goals of this GreenInfra4Beira project. As described in paragraph 1.2 the goal of this project is to develop a strong and resilient green infrastructure ES network for Chota. The GreenInfra4Beira project addresses issues of local water management and the availability of water for the creation of optimum conditions for an attractive and useful green infrastructure for the urban population.

Also corresponding with the goals of the project we will strive to implement efficient and cost-effective measures. The measures as proposed for Chota not necessarily are solely 'green' infrastructural measures, but when necessary, also a 'grey' infrastructure or combinations of grey and green infrastructure might be the most efficient. In other words we analysed combinations of 'hard' and 'soft' engineering as part of our combined system of solutions and measures for Chota.

Figure 22. Different types of green infrastructure: Trees, wetlands, ponds or retention basins

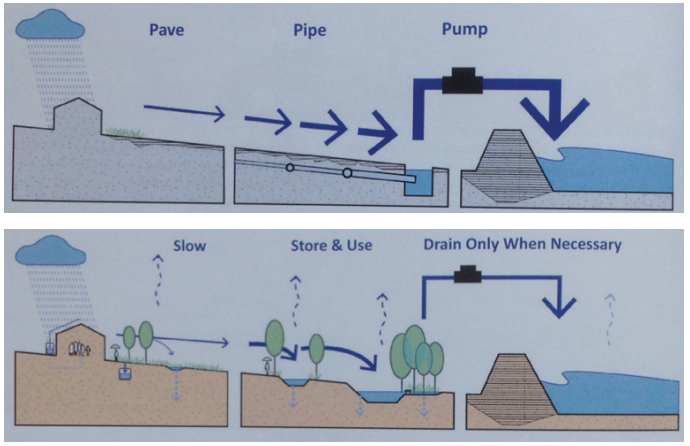


Figure 23.
Above: existing approach to Stormwater Management: "Pave, Pipe, Pump" and its consequences
Below: *Storage-based Stormwater Approach: Passive strategies work with nature*

3.3 A combined network of primary, secondary and tertiary measures

Part of the vision towards the network will be to understand the hierarchy in the local water system. Chota is not an island, unrelated to the neighbouring areas. Therefore we determined a primary, secondary and tertiary level within the water system. This gives us the opportunity to combine bottom-up approach with a top-down approach of the water system in Chota.
The design of the Green Infrastructure was made together with local stakeholders and participants from the Chota Waterboard.

3.3.1 Design Workshop

In November 2014 the worksteam organized a multiple-day workshop in the Chota neighbourhood and at the municipal office, to better understand the possibilities of a Green Infrastructure in Chota. Together with local stakeholders we searched for appropriate measures, we discussed solutions and we designed a specific local Green Infrastructure.

Figure 24 represents the outcome of these workshops and discussions, in a schematic way. The details of the proposed measures can be found in paragraphs 3.3.2 and 3.3.3..

3.3.2 Measures

Measures against the flooding problems in Chota and Maraza are based on two principles:
i) ecosystem-based, which means that the potential of nature is effectively used to deal with excess water, and;
ii) interlinking, to make sure that the measures act as network that will drain the area. The measures vary in function and size at different locations in the plan area, customized to the local need and the role in the overall water management system.

Figure 24 Result of the m,ultiple-day workshop in Chota

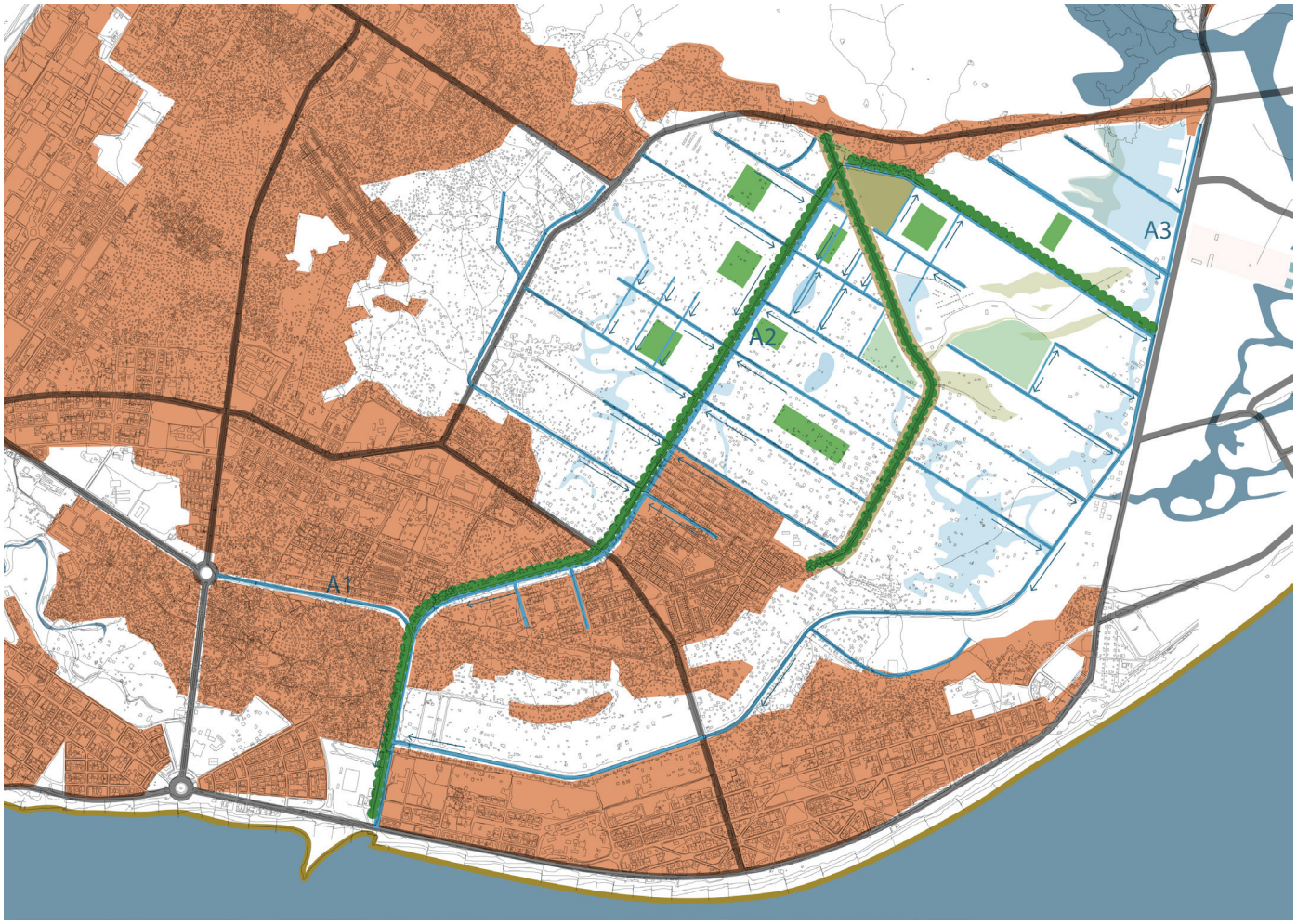


Figure 25. Digital reproduction of the outcome of the workshop as shown in the previous figure

In order to design an interconnecting system of measures, there can be distinguished three different layers of Storage based stormwater approach:

Step 1: House, Roofs and Plots	Tertiary water system
Step 2: Paths and Communal areas	Tertiary water system
Step 3: Public Space (roads, parks, ponds)	Secondary water system
Step 4: Canals and Retention basins	Primary water system

Below the different measures are listed per sub area:

Area 1 (Chota, west-side of airport road)

Large scale

- Bacias de retenção com infiltração / Bacias de retenção largas: Large retention basin to accumulate rain water in north east corner of residential area . In the higher areas this will be combined with water infiltration
- Canais de drenagens largas: Widening main (AI, AII, AII) and sub channels to create more retention area and guide water towards lagoon. It should be noted that for a flat area such as Chota-Estoril, it would be logical to provide more connections between the various primary drainage channels in order to optimize the discharge capacity of the system over the complete area (multi-directional flows in looped networks). In our design for Chota multiple connections are proposed between Channels AII and AIII.

Small scale

- Bacias de retenção pequena: Small retention basins that act as storage at building block level
- Dry, shallow ditches from plots to channels, to drain the plots Pequenos canais / “Bioswales” / “wadi’s”
- Cobertura de solo por arbustos, arvores: Trees and shrub at the plots to evaporate rain water, and support cooling of the plot
- Estradas verdes: Street trees, to lower temperature, and create a nice appearance of the area.
- Area 2 (south-eastside of airport road, south of Golden Peacock Resort)

Large scale

- Pântanos urbanos / plantas aquáticas: A purifying swamp, that will clean the storm water that enters area 2 from the west side of the airport road
- Compartimentos: Create a freshwater lake on sandy soil that acts as local retention and as beautiful water body for wildlife and tourism

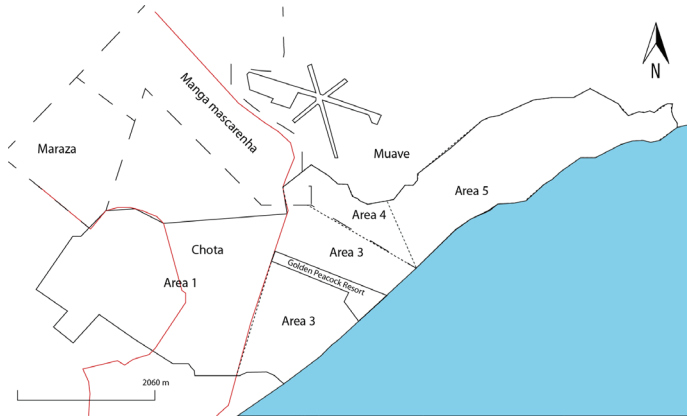


Figure 26. The areas of the measures Green Infrastructure Chota.

Area 3 (North-east of airport road, north of Golden Peacock Resort)

Large scale

- Bacias de retenção largas: Lagoon (ca. 150 ha) with urban developments and ecological zones, that acts as a large retention base. The lagoon will be located with an overlap to area 4.

Area 4 (Muave, south of fisher settlement road

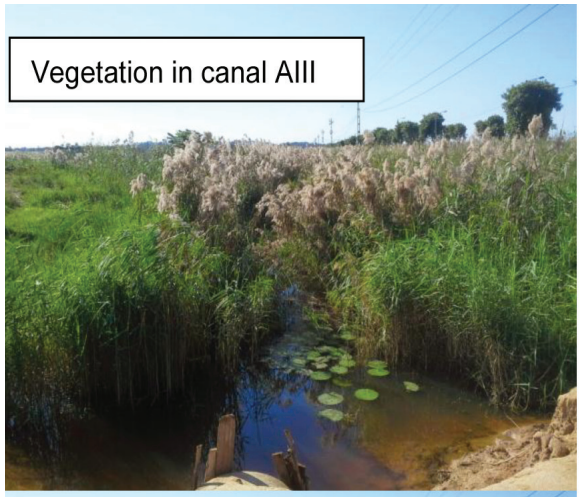
Large scale

- Lagoon, see area 3. Bacias de retenção largas
- Houses surrounded by dikes against flooding Casas protegidas as inundações
- Housing plots, elevated by sand or clay, to protect against flooding Casas elevados

Area 5 (Muave, north of fisher settlement road)

Large scale

- Channel (10-15 m width) that will connect the lagoon in Chota (area 3&4) with a new outlet at Rio Maria and rehabilitation of the Rio Macuti. The only outlet at Palmeiras poses a long-term threat towards a sustainable solution for Beira flooding. Especially as Beira is characterized as a booming city in times of climate change, there is the need for a long term solution, with several outlets. In the near future the Palmeiras outlet will be supported by the rehabilitation of the Rio Chiveve, which serves the south-western parts of Chota, including the city centre. However to solve the flooding problems of the booming neighbourhoods in the northeastern districts, it is necessary to implement a north-eastern outlet. This outlet is to be situated near the current Rio Mario outlet, to the north east of Muave.


Vegetation in canal AIII


Culvert in canal AIII


Vegetation in secondary canal


Man indicating water levels after stormwater events secondary canal

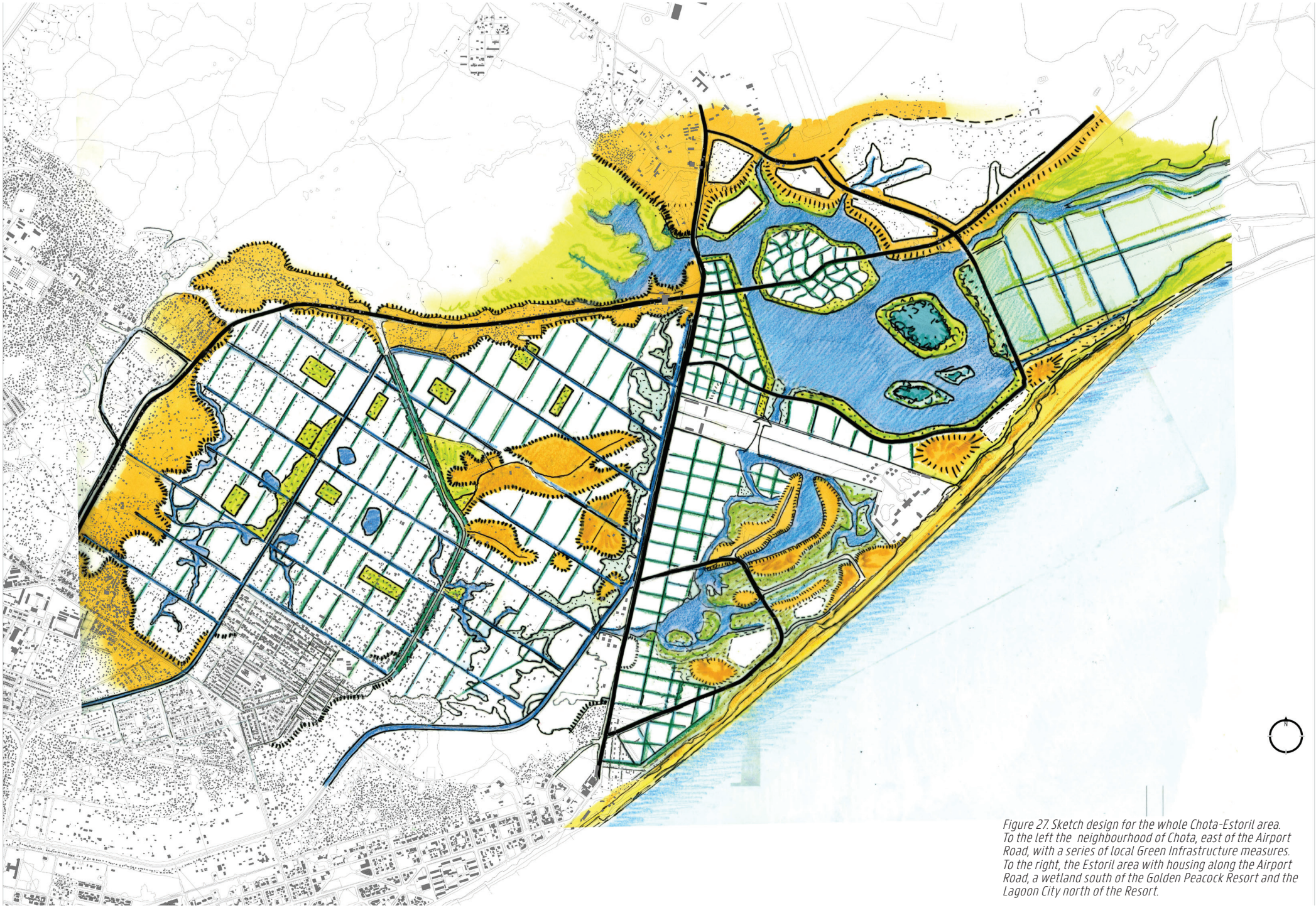


Figure 27. Sketch design for the whole Chota-Estoril area. To the left the neighbourhood of Chota, east of the Airport Road, with a series of local Green Infrastructure measures. To the right, the Estoril area with housing along the Airport Road, a wetland south of the Golden Peacock Resort and the Lagoon City north of the Resort.

Connections

Key connections

- Bridge (5m width) between area 1 and 2 (south at airport road)
- Bridge (5m width) between area 1 and 2 (north at airport road)
- Bridge (5m width) between Maraze and area 3

Bridge (5m width) and channel (at Peacock Resort, connecting areas 2 and 3)

- Bridge (5 m width) (connecting Muave at both sides of fisher settlement road)
- Outlet (connecting Muave with sea)

Local connections

- Large culverts in channels at entry roads of houses that currently create barriers in the water system Conexão/ / interligação de vazão de agua For a good functioning, a minimum of 2-5 meter width (e.g. 3-6 pipes of 80 cm diameter each) is necessary, depending on the location

3.4 Designing the Primary and Secondary system

The principal components of the primary drainage system in eastern Beira and Chota are the tidal outlet of Palmeiras and the primary drainage channels A1, AII and AIII. The drainage system in Chota further consists of smaller drains in east-west direction. These drains are connected to the main Canals (AII and AIII), flowing in southern direction towards the outlet at Palmeiras. In Chota the worst problems are in the north-west, which drains towards Canal AIII.

The drainage capacity of the channels is limited, due to several reasons. In the first place a 3Di analysis shows that the canals are slightly elevated in relation to the areas that they serve for drainage. Especially canal AIII has

Figure 28. Primary and secundary measures: improving the existing channels in Chota

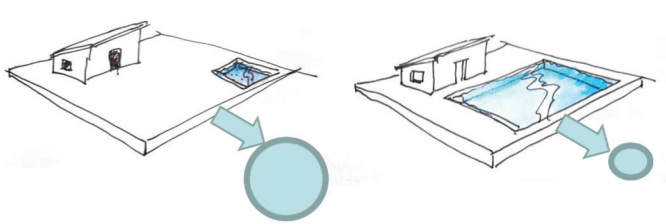
a very limited drainage according to height differences between the low land and the slightly elevated canal.
Second, at field visits it was observed that the flow in many canals is obstructed due to the presence of vegetation, causing a significant reduction of the discharge capacity. Also, many blockages such as dams are present. Sometimes a culvert is part of these dams. As the dimensions of these culverts are limited, they also reduce the discharge capacity.

Assumptions
The observed secondary canals have a typical cross-section with an estimated width of 4 meters, a water depth of 1 meter and sidewall slopes of 1:2 (vertical-horizontal). Canals have a relatively low flow velocity of 0.2 m/s during storm water conditions, which means that discharge is around 0.4 m3/s. With a surface area of Chota of around 40 hectares, this equals 10 l/s/hectare. We assume a high runoff coefficient of 0.8, which means that eventually 80% of the rainfall results in runoff during extreme rainfall events with long duration.

The project for the rehabilitation of the stormwater drainage system (TPF Planege, see paragraph 2.4) focuses on a substantial improvement of the drainage conditions of the districts Maraza, Mananga and Munhave and a partial improvement of the drainage conditions in the districts Matacuane, Chota, Macurungo and Macuti. The project only provides primary and secondary drainage infrastructure. The design also includes a future retention basin at Maraza and the southern branch of Rio Maria. However, the TPF Planege project only provided primary and secondary drainage infrastructure. The tertiary system remains the responsibility by the District Municipal Representatives. This is also the case for Chota, so one of the components of the GreenInfra4Beira project is the focus on solving local drainage problems by investigating various aspects of the development of the tertiary drainage system.

Assessment required storage capacity
During interviews (Witteveen + Bos October 2014), local residents revealed that flooding occurs almost every year. One of the possible options to mitigate the flooding, besides retaining and discharging, is storing water by creating extra storage capacity in the water system. We can assess the amount of storage that is needed by making a comparison of the estimated current drainage capacity of a typical secondary canal with the discharge resulting from stormwater events. To deal with a storm water event with a return period of 10 years almost 1 million m3 storage volume is needed.

The excavated soil can be used for filling/levelling in areas where new houses will be constructed, thus closing the ground balance. This will reduce the risk of inundation for new developments and results in lower construction costs.



Retenção: 1200 m3/ha (T = 10 ano)
Capacidade de drenagem: 10 l/s/ha

3.5 Designing the Tertiary system

It was stated above that water management in Chota is the responsibility of the local water board. Most of the residents of Chota think it is the responsibility of the municipality to solve water related problems such as flooding. For this reason the workshops held in November 2014, involved the local water board and interviews were held with residents.

Goals of the proposed measures:
1. Improving the quality of life inChota
2. A maximum decrease of flooding and a higher resilience to climate change
3. Increasing the drainage and retention capacity
4. Increase the awareness amongst the citizens
5. Improving the maintanance of the drainage channels
6. Dedicate retention areas within the urban neighbourhoods.

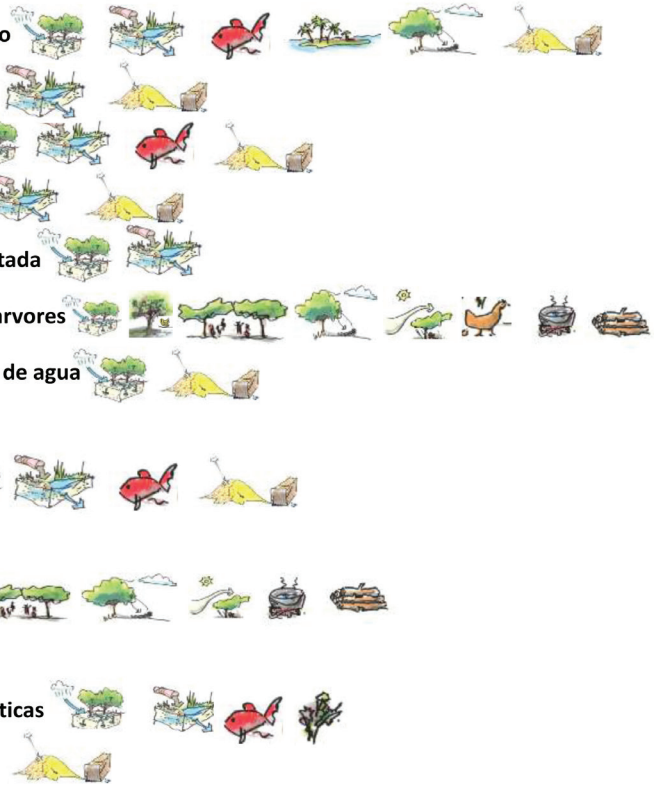
Short term (months)
- Clean and increase width of the channels
- Remove obstructions and install large culverts to bridges
- Retention in playing fields

Media and long term (1-5 years)
- Retention Basins
- small channels
- infiltration in sandy soils
- Increasing green areas (plant trees and shrubs)

Long-term (five years more)
- Development of the lagoon area and a new connection to the sea

Description of the tertiary measures as proposed during the workshop

- **Bacias de retenção com infiltração**
- **Bacias de retenção largas**
- **Bacias de retenção pequena**
- **“Bioswales” / “wadi’s”**
- **Capacidade de infiltração aumentada**
- **Cobertura de solo por arbustos, arvores**
- **Conexão/ / interligação de vazão de agua**
- **Compartimentos**
- **Canais de drenagens largas**
- **Casas elevados**
- **Estradas verdes**
- **Casas protegidas as inundações**
- **Pântanos urbanos / plantas aquáticas**
- **Pequenos canais**



- retention basin with infiltration
- large retention basins
- Small retention basins
- “Bioswales” / “wadi’s”
- increased infiltration capacity
- soil cover by bushes, trees
- Connection / / water flow interconnection
- Compartments
- Wider drainage channels
- Higher Houses
- Green Roads
- floods protected houses
- Urban Wetlands / aquatic plants
- Small channels

Figure 29. Green Infrastructure. Tertiary measures: soil cover by bushes, shrubs and trees

Figure 30. Green Infrastructure. Tertiary measures: connections between the plots / communal areas and channels..

Figure 31. Green Infrastructure. Tertiary measures: improving the infiltration capacity by infiltration wells

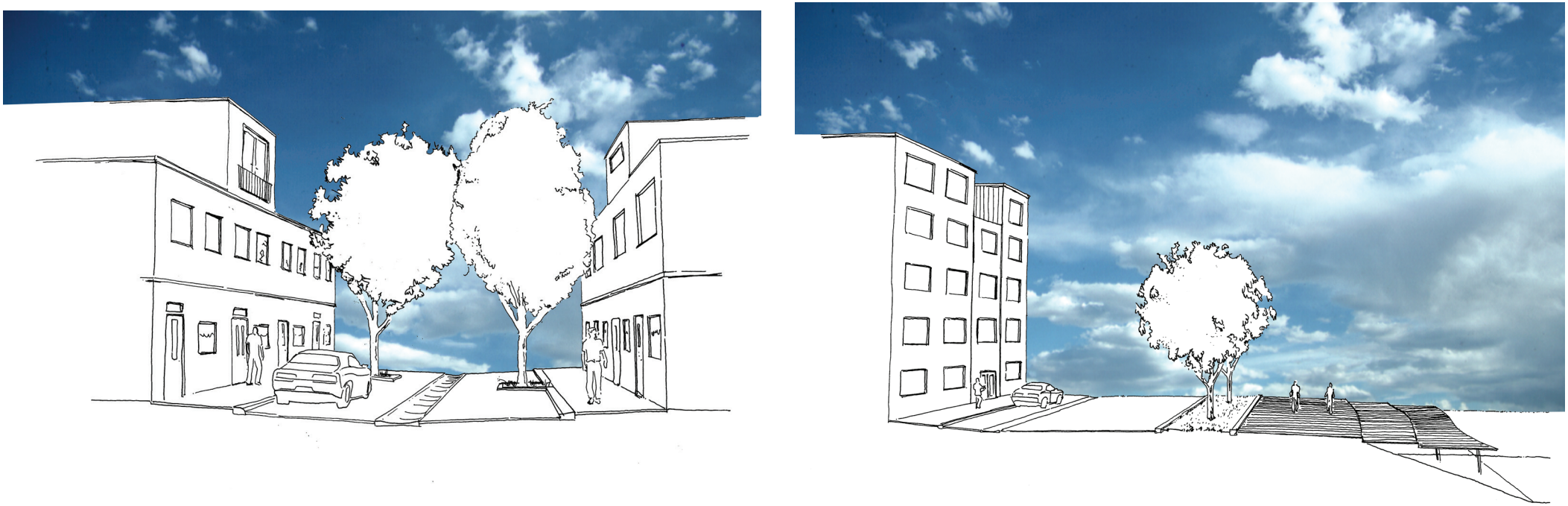


Figure 32. Green Infrastructure. Tertiary measures: improving the drainage capacity by gutters and bioswales

Figure 33. Green Infrastructure. Tertiary measures: improving the drainage capacity by retention basins (above) and sports fields (below)

3.6 Summary GreenInfra-4Chota

The proposed local drainage system and water storage in Chota water system will help in decreasing the flood volume. For functioning in long term it is also important to improve and maintain the drainage capacity of the water system itself. Currently, many of the secondary drains are blocked with vegetation (mainly reed). The maintenance as provided by the municipality, is digging the channels once a year by a digging machine (figure 34). Most of the (side)arms are cleared of reed.

Also dams are present, limiting or even completely blocking the flow. With the expected urban expansion in the Chota area, it is advised to align the drainage canals on a regular basis and to remove blockages, e.g. by adding culverts in the smaller canals and bridges over the larger canals.
By designing structures such as culverts and bridges in an early stage of the development of new urban areas, many of the current problems regarding discharge capacity can be prevented beforehand.

Residents see a solution in the deblock of the channel. Some suggest the need for an organization or institution, but feel incompetent for this and see the municipality responsible. Now some have to solve it by themselves by elevating the house with sand or even begin the floor a meter higher. There are also some ditches to the channel, but these have no effect when the channel is blocked.

Another response to the flooding and its related diseases is the construction of septic tanks. This system prevents the floods from mixing with the sewage water, to prevent waste and diseases.

Solutions to the flooding problem have a social-economic and a technical aspect. Socially, in awareness and institutions. Technically, in the improvement of the channel and sewage systems, better maintenance, water regulating constructions, elevation of houses and smarter allocation of buildings (e.g. more efficient, on higher grounds).

The drainage of the area will result in a lower water level. This can have consequences for the vegetation. Rice production may decrease. Residents react different upon this idea. Some say that it is no problem for the rice since rain will bring enough water for the rice. Others say that the rice will not stand anymore, but that it is no problem because the whole area will be urbanized.

Figure 34. Maintenance of the channel by a digging machine

Figure 35. People living half in the channel reduce its draining capacity

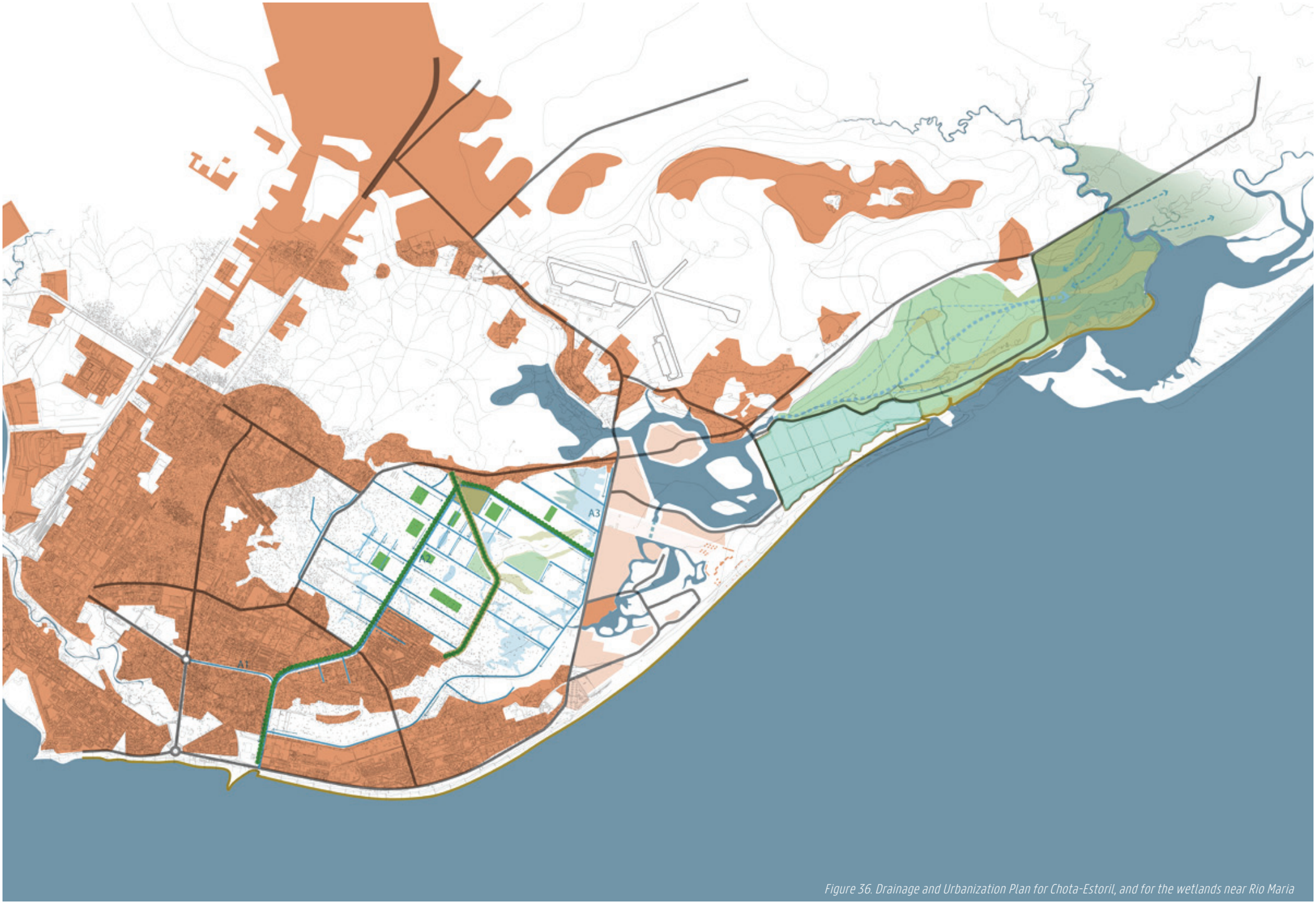


Figure 36. Drainage and Urbanization Plan for Chota-Estoril, and for the wetlands near Rio Maria

4 Chota - Estoril Lagoon

Due to the urbanization not all required retention capacity can be implemented in Chota and Maraza. Another problem is the limited capacity of the present outlet at Palmeiras. The construction of a lagoon combined with a new outlet can solve this problem.

The low-lying terrain east of Estrada Carlos Pereira offers great potential for the creation of additional retention. In the past this area has been a lagoon, which has silted up under the influence of incoming and outgoing tides. Currently, the lowest point of this terrain is approximately 1 m above mean sea level. A retention basin can be created by excavating the terrain, possibly to 2 m - MSL. As Beira needs much soil material for land fill in flood prone areas, the excavation may be arranged in an economically attractive way through excavation concessions. Figure 36 shows the potential extent of this future lagoon (note: already now various houses and other infrastructure building concessions have been given in this low-lying area).

In the Masterplan Beira the land use in this area is shown partly as recreational and partly as existing urban or urban open space (could be a lake). However, at least 5 – 10 km2 is wetland area and without extensive land fill it is uninhabitable. In the central area of Estoril, the land is inhabited by the Golden Peacock Resort. However, the area to the south and north-east of this resort is still (partly) available.
In April 2015, the area has been visited by the work team and the Beira City Counsel to inspect the status of the area. It was analysed that parts of the area is given in concessions for housing or tourism facilities, but also large parts are characterized by extensive agricultural land use with a very low economic return. It should be possible to create a lagoon of at least 150 hectares.

Given its purpose to provide retention in the drainage system, it is foreseen to create a multipurpose water body which provides attractive space for housing development, recreation facilities and tourism facilities. Also the natural quality of the area can be lifted by creating a lagoon with a wetland habitat, which facilitates a high level of biodiversity and attractive conditions for fish reproduction.

The southern longitudinal basin has to be realized in an area that is already under development. Parts along the Estrada Carlos Pereira and near the dunes are occupied by housing or concessions. However a basin in this area is of the utmost importance and space will be reserved for its realization.

The southern and central part of the lagoon will be surrounded by urban developments and tourism facilities. The north-eastern branch and the connection to Maraza basin are primarily reserved for natural developments, tourism and agriculture. These areas are characterized as low-lying wetlands, partly with mangrove vegetation behind the narrow dune-ridge. Lessons in Beira have learnt that reservations for such terrains should be made very early and consistently. In general, given the general drainage conditions in these districts of Beira, it is highly recommended to avoid land development for housing or commercial purposes below levels of 2 meters + MSL.

4.1 Dimensioning

For the dimensioning of the lagoon, the required area of 150 ha, as investigated by Deltares (Verweij), will be taken as a starting point. On the basis of the DEM and the map showing terrains which have not yet been commissioned to private parties, the area of the future lagoon will be delineated and connected to Rio Maria.
For the connection(s) to the ocean the following options will have to be investigated:

1. Open connection between lagoon and ocean via Rio Maria;
2. An additional open connection to the ocean via an additional outlet through the dunes;
3. Implementing controllable outlet structures in the outlets, in order to get more control on water levels and the flushing of ocean water through the lagoon.

In first instance it will be investigated if the connections can remain open, avoiding the implementation of hydraulic structures. Apart from saving costs, the simpler system will also be more sustainable, at least for decades to come.

4.2 Analysis of the Hydraulic Functioning of the Beira Lagoon

Within the project GreenInfra4Beira, the investigation of the hydraulic functioning of a future lagoon at Chota has been based upon a sensitivity

analysis of the influence of various design parameters. More detailed analyses are left to follow-up projects to be initiated in Phase 2 of the further development of Beira's drainage system.

In the current study, it is assumed that the lagoon can function well if connected to the ocean via one single outlet only. For the time being, the exact location and shape is not very relevant. Further investigations will point out which area is available for the lagoon and what kind of composition of basins and connecting channels it will take. Most likely, it will be impossible to make the lagoon function satisfactorily, purely on the basis of natural components (fractions of lagoon areas and rather natural connecting channels). In comparison with most natural lagoons, the available area is small, as much of the original lagoon area has already been commissioned for a variety of land development projects. Without the implementation of additional hydraulic control structures it will be difficult to assure a reasonably small range of water level fluctuations in the lagoon.

Optimum control of water levels under tidal conditions is assured when the control structures are equipped with movable gates. However, such gates will require rather complicated maintenance. For this reason, the current study only considers the control of the system on the basis of fixed hydraulic structures. In order to investigate various design options, a simple 1D SOBEK flow model has been developed with the lagoon schematized as one single storage reservoir (Figure 37).

Figure 37 SOBEK 1D Flow model schematization for Chota Lagoon reference design

At the downstream end, the lagoon is connected to Maria River, which in turn is linked to the ocean via an existing lagoon. The tidal level at the ocean has been simplified to a sinusoidal variation with a period of 12 hours. Its amplitude is varying over a period of two weeks following a sinusoidal function ranging between 0.5 and 3.5 meters, as shown in figure 38.

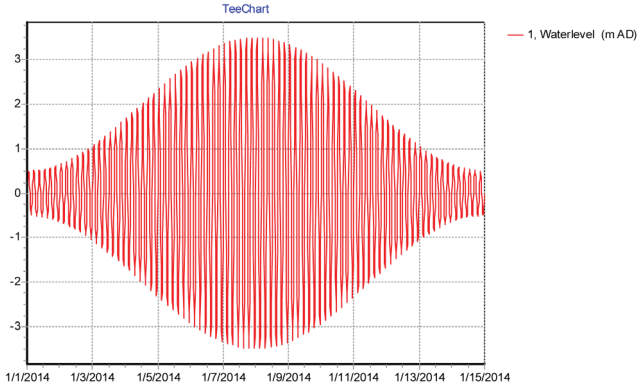


Figure 38. Schematized ocean tidal level variation over a 14 day period

At the upstream end, two runoff hydrographs have been given, as obtained from the recent drainage rehabilitation Phase 1 study of the Portuguese consultant TPF. Both hydrographs have been computed for a T10 event, including expected climate change impacts, for the drainage areas Maraza and Chota, respectively, as shown in figure 39.

The total volume of runoff from both areas is nearly 530,000 m3, leading to increased lagoon water levels of 0.53 and 0.26 cm, for lagoon areas of 100 and 200 ha, respectively, if no outflow could take place due to high tidal levels at the ocean. As high tides will block outflow only for a few hours and the Chota runoff extends over 40 cm for a 100 ha lagoon area.

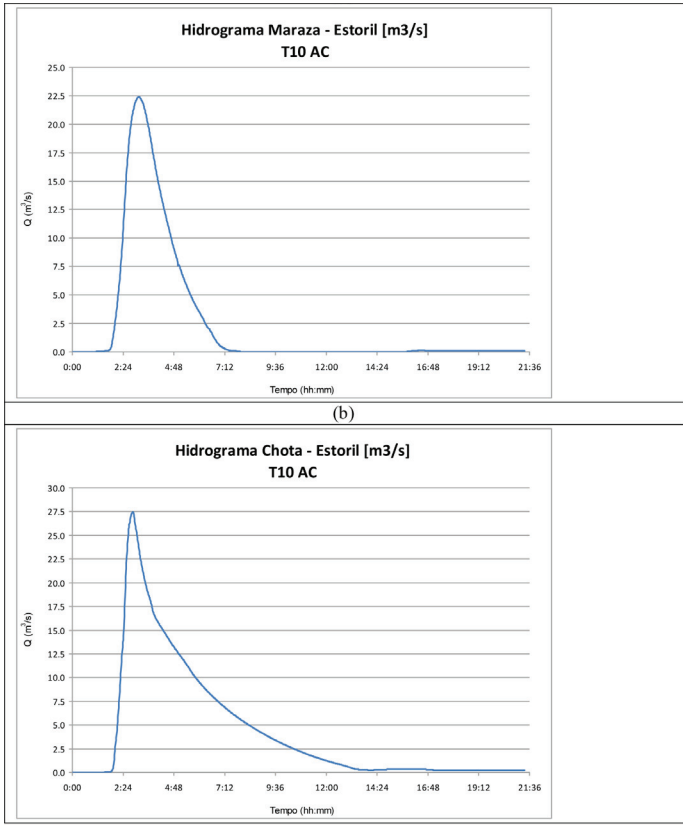


Figure 39. T10 runoff hydrographs from (a) Maraza and (b) Chota areas, respectively

For the reference situation, the following design parameters have been assumed:

- lagoon surface area 100 ha;
- lagoon bed level at -2 m;
- trapezoidal outlet channel with a bed level at -2 m, bed width of 10 m, side slopes of 1:2, Manning n=0.03 and a length of 3.4 km;
- no concrete structures along the outlet channel.

4.3 Design facts

The runoff to the new lagoon amounts to 0.75 Mm³, for a 1 in 10 year storm event, including climate change impact. This would lead to a 75 cm increase in level for a 100 ha lagoon size, if runoff would be blocked due to high tides at the ocean.
Lagoon bed level: 2.00 meters below MSL

Resulting lagoon water level variations for this design are shown in figure 40
The highest computed lagoon water level for this design is 1.79 m above mean sea level. Although this level might still be acceptable, a more sustainable solution would be to limit the maximum level to 1.00 m above mean sea level. Therefore, the following sensitivity tests were made, all starting from the reference case:
1. Increase the surface area of the lagoon to 200 ha;
2. Increase the length of the outlet channel by a factor 2;

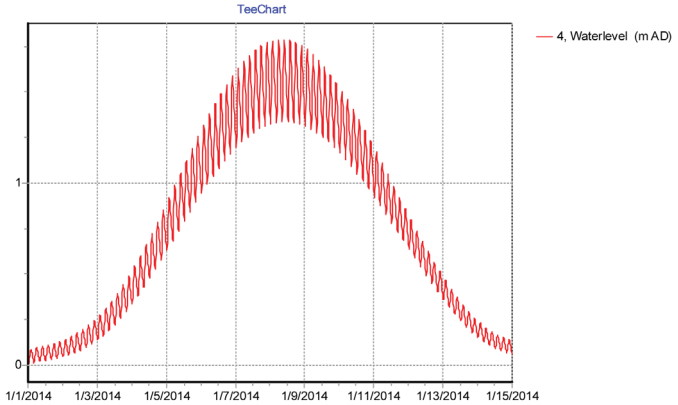


Figure 40. Lagoon tidal variation for the reference design over a period of 14 days

3. Increase the channel roughness to Manning n=0.04;
4. Increase lagoon and outlet channel depth to 3.00 m below MSL;
5. Introduce in the outlet channel a hydraulic structure with a width of 3 m;
6. Introduce a hydraulic structure with different flow contraction coefficients: 0.7 for inflow and 1.0 for outflow;
7. Additional similar structure placed sequentially.

The results of the various tests, in terms of impact on the maximum lagoon water levels are shown in the table.

Case	Intervention	Maximum lagoon water level (m)
0	Reference case	1.79
1	Lagoon area 200 ha	1.65
2	Double length outlet channel	1.70
3	Outlet channel Manning n=0.04	1.64
4	Lagoon and outlet channel depth at -3 m	1.75
5	ixed hydraulic structure with width of 3.00 m	1.46
6	Same structure with contraction coefficient 0.7 for inflow and 1.0 for outflow	1.07

Table Maximum Lagoon water levels resulting from various interventions in the system

From the results presented in the table it can be concluded that without hydraulic structures it will be virtually impossible to achieve + 1 m water levels in the lagoon under tidal conditions. With hydraulic structures a further reduction is possible. A special design favouring outflow from the lagoon over inflow, enables a further drawdown of the maximum lagoon water level.
Different contraction coefficients for both flow directions can be achieved with a special design of the weir side walls. In the design of the lagoon this can very well be combined with bridges that have to be introduced anyway, to connect both sides of the outlet channel. There should be no problem in keeping the maximum lagoon water level below +1 m under tidal conditions and below +1.40 m under combined storm and peak tidal conditions, without the use of movable gates. This leaves a slope of at least 10-4 for the design of the primarily drainage channels discharging into the lagoon. It is advised to design such structures with the option to install movable gates in the future, if climate change impacts would require such solution.

4.4 Connections

The schematic design of the new lagoon and its connections towards Chota, Maraza and the Indian Ocean is shown in figure 36. The central lagoon area is the main retention basin of around 150 hectare. To the south of this basin, and also to the south of the Golden Peacock Resort there has to be created a longitudinal retention basin, connected to the primary drainage channel AIII.
There is also a connection with the Maraza basin, as provisions have been made by TPF Planege. The third connection runs to Rio Maria and its estuary along the Indian Ocean coast. This will be a major new outlet for the whole primary system.
There will be an open connection between the lagoon and the ocean via Rio Maria as well as an additional open connection to the ocean via an optional outlet through the dunes. In the first instance the implementation of hydraulic structures is avoided.
The connection to Rio Maria by a new canal is judged on the impact of sediment moving in and out of the channel, in particular during the dry season. One impact may be the intrusion of sediment into the lagoon, another the possible erosion or degradation of the channel connecting the lagoon to the estuary.
If an additional outlet is created it may lead to a sediment spit into the sea and erosion of the coast in south-eastern direction. Such process is already present in the current situation.

There should also be a connection between the Maraza Basin and the future Chota-Estoril Basin (lagoon), as provisions have been made for this in the detailed design of the Maraza Basin.

Key connections

- Bridge (5m width) between area 1 and 2 (south at airport road);
- Bridge (5m width) between area 1 and 2 (north at airport road);
- Bridge (5m width) between Maraze and area 3;
- Bridge (5m width) and channel (at Peacock Resort, connecting areas 2 and 3);
- Bridge (5 m width) (connecting Muave at both sides of fisher settlement road);
- Outlet (connecting Muave with sea).

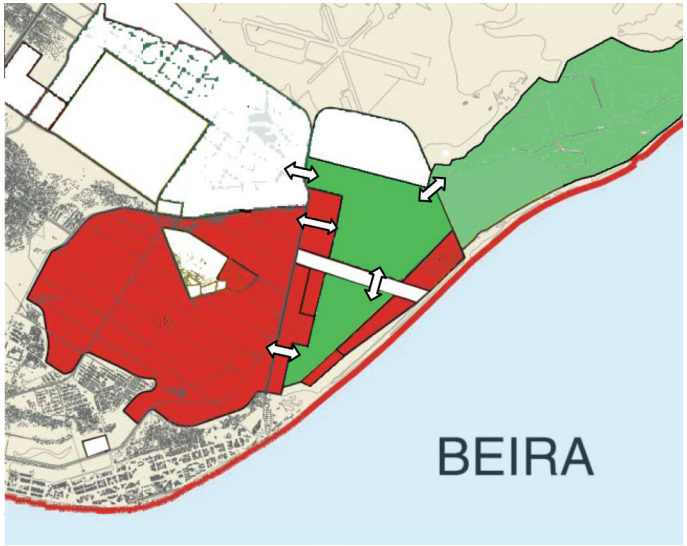


Figure 41. Connections between lagoon and surrounding areas

4.5 Design

Given its purpose to provide retention in the drainage system, it is foreseen to create a multipurpose water body which provides attractive space around it for urban development, recreation facilities and tourism. Developed as a lagoon, it facilitates the development of green infrastructure with a high level of biodiversity and attractive conditions for fish reproduction. As a principal, the development around the lagoon should return the investments required for its creation.

The water quality will be increased by creating green zones around the lagoon, creating biodiversity and facilities for recreation.

Outlet and inlet water exchange with the sea can be arranged in various ways, so as to create the best mean water level to facilitate the drainage of Beira and to ensure the best water quality and environmental conditions, with a high biodiversity. It also may serve as an attractive area for fish reproduction. The sketches show how such lagoon area may be developed as a natural waterbody with adjoining green zones with attractive possibilities to create urban development, boulevards and urban facilities

Figure 42. Reference of an inland lagoon

Figure 43. Boulevard along the edge of the lagoon

in the area in between the Estrada Carlos Pereira.
In the central parts of the lagoon we will be able to create a Lagoon City, consisting of an island, with green banks and housing in low and medium heights. The structure of this island follows the original patterns of the machambas, and thus offers a free winding structure of intimate roads, with an abundance of green in the streets and the gardens, as opposite to the grid-like structures of many quarters in Beira.

To the east and the south (bordering the Golden Peacock Resort) we find space for villa-neighbourhoods, recreational facilities such as resorts, beach restaurants and beach clubs in a natural setting of dunes. It may be clear that this drainage option can provide a high return on investments.

4.6 Morphology

A possible risk for the system is the deposition of sediment into the lagoon and in the outlet channel. For this reason the outlet of the lagoon has been positioned in the Maria River lagoon. It is expected that this lagoon has less sediment in motion than the ocean itself, with its long shore sediment transport. The connection to Rio Maria will have to be judged on the impacts of sediment moving in and out of this channel, in particular during the dry season. One impact may be the intrusion of sediment into the lagoon. Another impact is the possible erosion or degradation of the channel connection estuary and lagoon.

Along the outlet channel, flow is predominantly towards the sea, while also the maximum flow velocities in this direction are higher than towards the lagoon. There is a high probability that sediment deposited in the canal temporarily, will be flushed out again.

However, near the hydraulic structures sediment may pile up and change the flow contraction coefficients at the structure. This would affect the maximum lagoon water levels. It is a problem that can be solved with maintenance. Also the sediment deposition in the lagoon can be solved with maintenance. The problem should be quantified at the level of detailed design, supported by sediment surveying and monitoring prior to the start of the design project. Detailed design should include the option of creating a second connecting between lagoon to ocean and investigating the morphological impacts.

If an additional outlet is created it may lead to a sediment spit into the sea and erosion of the coast in south-eastern direction. Such process is already present in the current situation. At this stage of the lagoon design only morphology expert advice is foreseen without modelling support.

4.7 Water quality and salinity of the lagoon

If the retention basin would just drain excess water uni-directionally to the sea it would be difficult to maintain a satisfactory water quality under the impact of large quantities of polluted runoff from Beira. It can be expected that the water quality would improve substantially if a continuous exchange with water from the ocean takes place. One of the principal outcomes of water quality modelling would be the answer to the question whether the lagoon would require two outlets or only one.
Judgment on the water quality will be supported by the use of a relatively simple mathematical model delivering state indicators for a number of substances, including salt. A simulation would be required over a complete year, with schematized intermittent inflow events, representing the total volume of drainage runoff and pollutants carried with it over the year. In addition, a sensitivity analysis of the impact of the depth of the lagoon will be made.

The lagoon receives salt water from the ocean and polluted surface runoff from the Beira drainage area. Even during neap tide periods, some ocean water reaches the lagoon, providing some dilution of the pollutants entering the lagoons during storms. As part of the current project some

investigations should be made into the water quality aspects, including salinity. This is best based upon the positioning of the lagoon on the map and creating a 2D SOBEK model for the lagoon area, connected to the drainage and outlet channels. Salt may intrude into the drainage channels from Maraza and Chota. If this is undesirable, a weir with a low lying crest may be installed in these channels.

4.8 Ecological conditions

Current conditions

The area where the proposed lagoon and wetlands are projected consists of a complex of different abiotic conditions, as investigated by Alterra Wageningen UR during fieldwork. Using soil drills up to 3 meter, the structure of the subsoil has been explored. Clearly, the soil structure demonstrates a rich history of subsequent erosion and sedimentation processes. In general, the area is covered by a layer of clay, with occasionally sandy remnants of old dunes (predominantly, excavated to ground level or beneath) and generally underlying the clay layer at higher depths. The thickness of the clay topsoil is variable, from several decimetres up to several meters. Underneath the clay, a sandy soil is present. When studied in more detail, the clay soil consists of several sublayers, each with a different composition of clay and other materials (sand, gravel, etc.). These different sublayers differ in permeability and other physical and chemical

characteristics. The soil drills show that the structure of these sublayers in the clay zone varies locally.

That the variety in abiotic conditions results in different vegetation and aquatic plant and animal life, was demonstrated during an inventory by Alterra Wageningen UR of more than 25 surface waters in the lagoon and surrounding areas. For each sample point information on a long list of (a) biotic parameters was collected. Key factors determining the ecological value are soil type, salinity level, organic pollution level, depth and underwater slope of the water body, overall size of the water body and connection to the broader water infrastructure, human use and maintenance. Types of water bodies range from pristine freshwater ponds with clear water and a rich aquatic wildlife and tidal mud plains with mangrove vegetation, mud skippers and fiddle craps, both at the far end of the study area, up to turbid, polluted water bodies like canals and small retention basins in the urban areas of Chota. The latter examples present a low diversity of general swamp plant species and a low abundance of wildlife. In terms of local climate the interviews of residents revealed that heat in the warm season and winds in the colder season are a source of complaints.

Recommendations for design and construction

- Planning land use while making use of the land ecological pattern and ecosystem services to preserve is an aspect that should obtain due attention during further plan development and motivation.
- Take the existing abiotic conditions (soil, groundwater) as starting point for design, to achieve the best ecosystem performance (e.g. clear water, rich biodiversity etc) at each location.
- In more detail: shape water bodies such that the right subsoil layers are exposed, and the right underwater slope will be created, to ensure that the preferred plant and animal life will develop.
- Separate polluted waters from pristine water bodies (e.g. a dune lake in the already excavated ancient dune area south of the Peacock resort).
- In the areas under tidal influence: shape an underwater slope that supports the development of mangrove in the banks of the water body.
- In the (purifying) wetland: create conditions for swamp vegetation, e.g. shallow waters where reed and other plants may grow.
- On the natural bank of the lagoon (ocean-side): create variety in the underwater profile which will result in a rich diversity of vegetation.
- For Chota district assure the preservation of groundwater and

investigate possibilities to increase infiltration, into deeper soil layers, possibly a ..

- In the residential areas, due consideration of wind directions for cooling but also for reducing cold wind, depending on the season, is needed. The choice of species, with leafs in cold or warm season, direction of plantation, can make a difference. Also in terms of provision of shade.
- Amenities of plantations of trees and shrubs in terms of beautification, sidewalks with attractive tree and shrub species, in terms of leaf, flower or odour must be paid attention to.
- Fruit trees in public spaces as well as on the compounds can be planted. Local tree nurseries do have such trees on offer. The local assortment can however be improved with more ornamental species. Especially for the higher income districts this might be interesting.

4.9 Conclusions

By creating a lagoon of around 150 hectares in Estoril, it becomes possible to drain the largest part of Chota, Maraza and Estoril via the lagoon and a new outlet at Rio Maria. The most important results will be solving the inundation problems in the northeastern parts of current and future Beira. Furtermore we see the following results:

1. Solving inundation problems in Beira-east
2. Earning money by urban development
3. 1.255 hectare of inundation free urban development area
4. Better living conditions
5. Better economic prospects
6. Co-benefits of green infrastructure
7. No relocations of current housing
8. 50 hectares extra land use for housing and tourism (extra to current concessions)

5 Business Case

5.1 Introduction

The previous steps resulted in a preliminary design for green infrastructures in Chota and plans for a 100 ha lagoon located north of Beira. This lagoon will function as a retention basin for Chota and other districts of Beira. Stakeholder Involvement was an important issue in the design process. Major steps in the design process have been made during the visit to Beira from 20 until 28 November 2014. Two design workshops with local stakeholders were organized. The team presented the preliminary design for green infra to the city council. The city council gave their (informal) support to the green infra plans.
The next step is to implement these plans. Two important aspects that will help to accelerate implementation:
1. The positive reaction of the city council, and other stakeholders we have spoken (people from Chota, AIAS, Donor-organizations who subscribe our approach).
2. The sense of urgency. All stakeholders agree that in the near future measures are needed because ongoing urbanization will make it more and more difficult to implement measures. Every month the space available for adaption measures becomes less.

At the moment the plan is not yet ready for starting construction works. Before starting construction activities the following conditions are required:
- Funds for detailed design, construction works are available.
- An organization to manage the implementation is established.
- An organization for maintenance is established.
- The needed area for storm water and other green infra measures should be available.

This chapter is a first step in solving the funding problems for the green infra projects in Chota. This report gives an overview of expected cost and benefits from implementing the proposed measures.

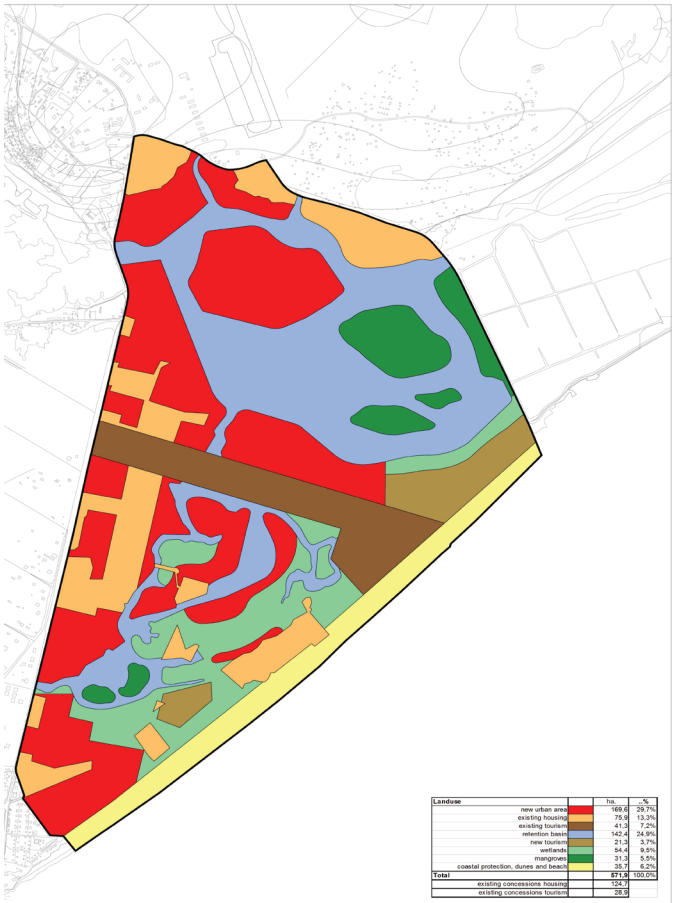


Figure 44. Land Use of the Lagoon City

5.2 Overview of expected costs

5.2.1 Green infra Measures

In an earlier stage the required discharge and retention capacity of the water system in Chota have been assessed. The capacities were assessed using basic hydrologic calculations. These calculations resulted in a preliminary design of canals and water retention. For detailed design more advanced calculation (modelling) is needed. The most important results from the calculations:
- For Chota approx. 1 million m3 water retention is needed.
- In the calculations we applied a drainage capacity of 10 l/s/ha.

Based on these assumptions a preliminary design of storm water and green infra measures was prepared. This design is based on input during workshops in Beira. The resulting design is presented in Chapter 3.

The preliminary design includes:
- Retention basins.
- Widening of existing canals.
- Planting trees along the canals.
- Introduce micro-drainage near the houses.
- Use sports fields as water retention.
- Combination of retention and infiltration in higher, sandy ridges.
- Replace dams with small culverts for larger culverts (especially in canal AIII at the north side of Chota).
- Remove reed vegetation to improve the discharge capacity.
- Construction of a 100 ha retention pond (lagoon) with a canal to convey storm water to the sea. This lagoon and canal do not only serve Chota, but will improve the drainage for a larger area.

Table 5.1 gives an overview of the dimensions of the proposed measures as presented to the city council.

measure	specification	remark
Retention basins/areas	330,000 m^3, 0,5 to 1 m deep	
Widening canals	180,000 m^3	make existing canals 10 m wider
Trees along the canals	4 km	
Water retention on sports fields	not specified	included in retentions basins
Combination retention/infiltration	60,000 m^3	2 m deep, 10 % of the area at the sand ridge
Replace dams by bridges or culverts	not specified	
Reed removal	not specified	
Lagoon including canal and outlet to the sea	100 ha	
Micro drainage	18,000 m^3 for a part of Chota (or 3,6 ha)	For only a part of Chota (35 ha) a sketch with a possible layout of micro drainage was prepared

Table 5.1 Dimensions of measures as presented to the council

For the cost benefit analyses more specific input is needed to assess the related cost. This means measures included in the plan have been specified in required actions and equipment. These specifications are based on expert judgement. Table 5.2 shows an overview of the specifications in the cost estimate.

measure	specification	remark
Retention basins/areas	combination of retention measures: 57 ha, average depth 1,5 m, 855,000 m^3	
Widening canals		
Combination retention/infiltration	120 infiltration shafts	
Trees along the canals	800 trees	
Water retention on sports fields	not specified	included in retentions basins
Replace dams by bridges or culverts	Construct several culverts in dams to increase the capacity. Assumption total length 600 m. Diameter 1 m	
Reed removal	10 ha	
Lagoon including canal and outlet to the sea	100 ha Lagoon, average depth 3 m For the lagoon, canal. outlet structure and property development around the lagoon 150 ha is needed 1 outlet structure	
Microdrainage	524,000 m^3 Based on 3.6 ha for an area of 35: Total area Chota: approx 764 ha Width bottom 0,5 m; dept 0,5m slopes 1:1	

Table 5.2 Dimensions input in cost etimate

5.2.2 Prices and other parameters cost estimate

For the Masterplan Beira an inventory of local prices was made. The results are used for this project. In the cost estimate the following prices and parameters are applied:

- Earth works: 0.94 USD/m3
- Culvert: 500 USD/m
- Infiltration shaft: 120 USD
- Tree: 50 USD
- Reed removal: 3.44 USD/m2
- Outlet structure: 2,750,000 USD/pcs
- Land rights: 2.5 USD/m2 for 150 ha (lagoon area). We assumed measures in Chota can (mostly) be implemented in public areas
- Maintenance 2 % of the investments cost/yr
- Construction period works in Chota: 5 year, starting in 2017
- Construction period lagoon: 7 year, starting in 2017
- Management cost: 30 %
- Contingency costing this phase: 40 %

The resulting costs are 26.6 million USD for the period 2017-2045. The graph in figure 45 shows the contribution of the individual measures. The most important costs are related to earth works (Lagoon, retention and microdrainage in Chota), land rights (Lagoon), maintenance and the outlet.

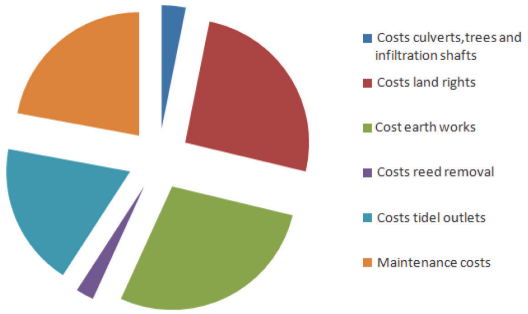


Figure 45 The contribution of the individual measures

5.3 Overview of expected benefits

The implementation of storm water and green infra measures will result in several benefits:

- Clay and sand come available from earth works; In Beira sand (and clay) are urgently needed for levelling lower areas and production of bricks.
- Retention ponds and the lagoon can be used for fish-farming.
- The lagoon can be used for recreational activities.
- The area around the lagoon can be developed as residential area.
- Avoided cost for direct damage as a result of flooding in Chota.
- Avoided cost as a result of reduction of the malaria casualties (unless the construction of retention ponds the total wet area will reduce strongly as a result of inundation prevention measures).

The following benefits are not included in this overview for Chota:

- Better drainage situation in the Maraza district (north of Chota).
- Increase of the value of real estate in the area as the drainage situation improves. The income related to the transfer tax for real estates will also increase. This means not only house-owners will profit. There will also be public benefits.

It is important to be aware not all benefits generate income for the organisation that implements and/or finances these measures. For example: the local population will profit from a reduction of the number of malaria diseases and avoided direct damage during a flood. But these benefits will not result in a (direct) financial benefit for the city or any other organisation. For other measures the implementing organisation might have financial benefits if a tax or permit can be introduced. For example: fish-farming or (commercial) recreational use of the lagoon.

The following prices and parameters have been used to assess the financial benefits:

- Soil becoming available from earth works: 50 % clay, 50 % sand;
- Revenue clay: 15 USD/m3 (based on an inventory in the Beira Masterplan project)
- Revenue sand: 12.50 USD/m3
- Revenue fish-farming: Chota 2,500 USD/year; Lagoon: 5,000 USD/year
- Revenue recreational use Lagoon: 5,000 USD/year;
- Revenue reed production: 500 USD/year
- Sale of residential plots near the lagoon: net revenue 7,500 USD/plot; 100 plots
- Avoided cost flooding: 5,000 USD/year as a result from measures in Chota and 5,000 USD/year as a result from the lagoon
- Avoided cost malaria: 5,000 USD/year

For the revenues of fish-farming, recreational uses, reed production, avoided flooding and avoided malaria no local information was available. These benefits have been assessed very roughly.
The expected benefits for the period until 2045 are: 61.6 million USD. The graph in figure 46 shows the contribution of the individual benefits. The most important revenues are expected from the sales of sand and clay. The other revenues are relatively small.

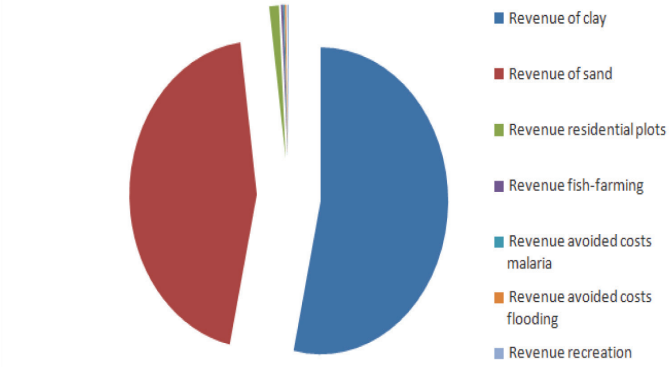


Figure 46 The contribution of the individual benefits

As the revenues from sales of clay and sand are very important for the overall cost-benefit analyses, we analysed the sensitivity for these parameters. The results are presented in paragraph 5.

Income from clay and sand: legal restriction
In our calculations the possible revenues from sales of clay and sand are very important. But according to the Mozambican law, organisations are not free to sale sand and clay from earth works without permission from higher authorities (national, province). This is an important issue in the expected benefits (>90 % of the benefits). The provincial or national authorities should permit the sale of sand or clay. What we understood at our visits: if the sand or clay will be used directly to level low areas nearby (for example property development near the lagoon) no permit is needed. This makes it worthwhile to prepare an inventory of possibilities to co-operate with new development in or near Chota (private houses) and the area north of Chota (where professional developers are building and planning property investment).

5.4 Resulting Financial Business case

As presented in the former sections of this report the expected costs and financial benefits are:

- Costs: 26.6 million USD.
- Benefits: 61.6 million USD.

Both are calculated for the period until 2045.
For an objective analysis the Net Present Value (NPV) is assessed. The NPV (before tax) is 27.9 million USD. Starting point in these calculations:

- Construction works in Chota start 1-1-2017 en will take 5 years.
- Construction works for the lagoon start 1-1-2017 and will take 7 years.
- Interest:
- Term debt margin 1.50 %
- Active senior term debt base rate profile 4.00 %

5.5 Sensitivity analyses

Sale of sand and clay

The assessed benefits are mostly revenues from selling sand and clay. A sensitivity analyses for this parameters has been prepared. Table 5.3 shows that a price of 5.5 USD/m3 is needed for a break even business case. If the value of clay is negligible, a price of 11 USD/m3 for sand is needed to equal costs and revenues.

Land rights

	price clay	price sand	NPV Profit before tax	diference
Base	15,00	12,50	27.900.000	
Price minus 1 USD	14,00	11,50	24.500.000	-3.400.000
Price plus 1 USD	16,00	13,50	31.300.000	3.400.000
Price clay = price sand	12,50	12,50	23.600.000	-4.300.000
Price clay and sand breakeven	5,50	5,50	8.000	-27.892.000
Price clay = 0 USD	-	12,50	2.200.000	-25.700.000
Price clay=0 and sand breakeven	-	11,00	7.000	-27.893.000

Table 5.3 Sensitivity analyses sand an clay

In this sensitivity analyses the influence of land right prices has been assessed. The analyses only focus on land rights for the lagoon (150 ha). We assume no land rights for measures in Chota have to be paid. The resulting calculations are presented in table 5.4.

assumption 150 ha for Lagoon	price		NPV	difference
Price 2,5 / m2	2,50		27.900.000	
Price 5 / m2	5,00		22.200.000	-5.700.000
Price 10 / m2	10,00		10.700.000	-17.200.000
Price 15 /m2	15,00		(800.000)	-28.700.000
Break even	14,85		57.000	-27.843.000

Table 5.4. Sensitivity analyses land rights lagoon

At a price of 14.85 USD/m2 the NPV drops to 0. At this price the investments and revenues are break even.

5.6 Conclusions

This preliminary assessment of expected costs and benefits shows a net profit. This means investing in green infra may result in important benefits and further development of the plans is advised. In these further steps a more accurate assessment of expected costs and especially the benefits is required: At this stage the accuracy of the presented figures is limited:

- Related to the expected cost: the accuracy will be about 40 % this is a normal range for (very) preliminary plans is presented in this report.
- Related to the expected benefits it is important to have a better assessment of the quantities of sand and clay (field survey) and the resulting revenues. This project will result in large quantities of sand and clay. As a result prices may decrease which will influence the business case importantly.
- The financial benefits for the Maraza district and the increasing value of real estate (including increase in real estate transfer tax) are not included.

Summary: expected cost and benefits

Our calculation shows the benefits are higher than the expected cost (62 and 27 million USD). This means from an economic point of view the project seems feasible. In this calculation not all benefits have yet been calculated, for instance

- Better drainage situation in the Maraza district (north of Chota).
- Increase of the value of real estate in the area as the drainage situation improves. The income related to the transfer tax for real estates will also increase.

Not all cost and benefits are known in detail. The outcome from the cost benefit-analyses largely depends on four parameters:

- Price of sand that becomes available during the construction works.
- Price of clay that becomes available during the construction works.
- The ratio between the volumes of sand and clay that become available.
- The land rights that have to be paid for the area (plots) that are needed for implementing green infra in Chota and the Lagoon north of Chota.

This report includes a sensitivity analyses for these parameters.

6 Valuation and recommendation

6.1 Valuation of the merits (valuate)

Infrastructure planning often negatively impacts communities by impacting environmental health. We discussed with the stakeholders the value of a wide variety of ecosystem services (ES), learn about applications of ES valuation and natural capital appraisal and download communication materials. While ecosystem valuation is certainly difficult and fraught with uncertainties, valuation can be monetary, but a lot of ES are hard to value in that way, so qualitative valuation might be even more crucial. The exercise of valuing the services of natural capital at the margin consists of determining the differences that relatively small changes in these services make to human welfare. The ES and functions do not necessarily show a one-to-one correspondence for every stakeholder. In some cases a single ES is the product of two or more ecosystem functions whereas in other cases a single ecosystem function contributes to two or more ES. The issue of valuation is inseparable from the choices and decisions we have to make about ecological systems.

The chains of effects from ES to human welfare can range from extremely simple to exceedingly complex. Many of the valuation techniques used in studies are based on attempts to estimate the willingness-to-pay of individuals for ecosystem services.

The underlying objective for this report is to solve the storm water problem in Beira, using a green infrastructure as a solution and at the same time, research the Ecosystem Services offered by this green infrastructure. The questions is, what can we do with the design of a green infrastructure? The green infrastructure for the pilot project of Chota offers a network of interconnected green areas and waterways (canals, wadi's basins). It promotes a strategic framework of ecosystem services as an alternative to the traditional 'grey' infrastructure. Our proposal for an interconnected green infrastructure builds on the already available and valuable ecosystems in Beira, such as

- Wetlands (e.g. water buffering, - purification, rice cultivation)
- Sand ridges (e.g. living place, gardens, water infiltration)
- Coastal (e.g. defends, recreation, water infiltration)

What we proposed for Chota is a more detailed study towards these interconnected green measures and Ecosystem Services. At the moment Chota still has many natural qualities and services. But Beira's urbanization is spreading out in the wetlands of Chota, changing its wetland into 'urban land'. Its ecosystem services like water buffering and rice cultivation will decrease while there is an increasing amount of people requesting for this ecosystem services. That is a conflicting paradox. The short term goal is to solve the annual flooding problems. A green infrastructure can do this through its capacity to buffer water in dedicated areas, such as ponds, canals, retention basins or sports fields. Whereby vegetation and basins will increase the infiltration capacity and keep the water in its place. The existing main channels AI, AII and AIII should be able to drain parts of Chota, but they don't have enough capacity and their levels are not fitted to do the job properly. Also the primary and secondary canals often are blocked by reed and recent constructions. In this sense, a blue infrastructure, without blockings, better connections and greater capacity would increase the buffering capacity and the drainage at the lowest areas. A green infrastructure with forests, parks and retention basins, would help buffer the water and prevents flash floods. Thus a green infrastructure in Chota would be of increasing value. Chota is urbanizing so fast that space for green infrastructure is under pressure and therefore there is an urgent need for implementation.

Next to helping solve the flooding problems and improve the drainage capacity, a green infrastructure also can solve other environmental problems (erosion, pests, waste) and add ecosystem services (fruits, wood, biodiversity). Interviews revealed that there are many other problems such as hard winds, struggle for basic needs (income, food, charcoal) and a lack of facilities (transport, schools, play fields). It would be very valuable if a green infrastructure could address the other problems as well; as a multifunctional merit.

6.2 Benefits of the project

Hydrologic benefits

1. Directing the storm water from Chota and Maraze no longer to the outlet at Palmeiras, but to a new outlet near Rio Maria, will relieve the pressure on the Palmeiras outlet and therefore lead to less flooding problems in the central part of Beira.
2. Implementing the measures will reduce flooding problems in Chota and Maraza (expected frequency will reduce from every year to every 10 years).
3. Guiding the storm water from the Chota residential district through a wetland (area 2) will purify the water from pollution, thereby increasing the water quality.

Economic benefits

4. Because the project will relief the flooding problems in the central part of Beira (see 1), this area becomes more interesting to (private) investors for economic (re)development.
5. Because the project will dramatically decrease the flooding problems in Chota and Maraza (see 2), these areas (together 1250 ha) become more interesting for economic (re)development.
6. Purifying the storm water from Beira and Maraza (see 3) will decrease pollution levels in the sea, thereby stimulating the marine ecosystem.
7. The development of the lagoons will create an attractive environment for people and wildlife. As a result, the lagoon city and other urban developments will become an interesting living and recreational area

for middle- and high-class residents of Beira.
8. The lagoons and wetlands will offer a beautiful place for ecotourism, especially along the dune area. The touristic value will attract investors to develop resorts, and will create jobs for the local people.
9. The overall business case for the development of the lagoon is positive. Sandy soil from the retention areas can be used for leveling residential and tourism developments.

Other benefits

10. Water management: decrease problems with malaria and water pollution, thereby increasing the health for the Beira residents.
11. Green infrastructure: more trees will provide shade and food for the residents in Chota
12. Permanent water (lagoon and other retention areas): places for fish farming

Win-win negotiation: designing of the green infra plan (negotiate)
How a strategy of win-win exploration is developed and implemented strongly influences its sustainability and credibility. National strategies help bring together diverse groups of stakeholders to build connections, exchange viewpoints, negotiate, and build a sustained political commitment. Local authorities play a vital role, given that it is at the local level that Beira citizens experience the impact of environmental climate change and degradation. Local authorities have proved to be willing innovators, offering opportunities to test policies and build consensus before scaling up. Here the stakeholders in a workshop will bring all elements together, i.e. use all the info as obtained in the previous step. Key here is to jointly design, negotiate and then agree upon the Green Infra for Beira plan.

Added value for Mozambique

The GreenInfra4Beira project provides an innovative methodology for planning of green infrastructure and solving flooding, erosion and health related problems in urban areas. Most of the Mozambican cities face similar problems as in Beira. Cities such as Maputo, Nacala, Nampula are faced with rapidly expanding urban areas and with the effects of uncontrolled growth due to a lack of planning for water related issues. This poses serious threats to the well-being and health of inhabitants and to the sustainability of their properties, investments and public infrastructure. By showing the results of our project to the relevant authorities at Municipal level, Provincial and national level (AIAS), and private parties with an economic interest in improved reliability (industries, business associations, banks etc.) and by linking up with ongoing programmes such as the Cities and Climate Change program of the World Bank, the results can be applied in other cities.Added value for the world water problems.

The consequences of this project for the local communities

In this project we studied the possibilities of an improved drainage for Chota as well as its impact on the overall water management. Improved drainage, despite its positive impacts, such as reduction of mortality and loss of production resulting from malaria, also has negative sides in terms of reduced water availability in the dry season. For this reason, green infrastructure in these areas would change as a result of dryer conditions. The objective of the GreenInfra4Beira project is to turn the changed water availability to the advantage of people living in Chota. For these reason, this project provided insight into the relation between a changing water balance and the green infrastructure. Specific tasks are listed as follows:

- Investigate the composition of current tree and plant species found around the houses in Chota and their importance for the local population. Use ranking to specify their importance;
- Investigate water needs for these species and the probability of maintaining these species under changed water availability conditions resulting from the improved drainage;
- Investigate options to retain water during the wet season for supplementary irrigation of town gardens in the (semi-) dry season;
- Investigate the possibility of introducing other useful plant species that will be better adapted to the improved drainage conditions;
- Produce sketches which visualize possible new green infrastructure providing optimal support to the people living in Chota.